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DIRECTORATE OF ENERGY MANAGEMENT

SAN ANTONIO AIR LOGISTICS CENTER

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INDUSTRY - MILITARY ENERGY SYMPOSIUM

21-23 OCTOBER 1980

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REPORT DOCUMENTATION PAGE

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20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

Publication contains the texts of 49 presentations by leading government and industry officials at the Industry-Military Energy Symposium, held in San Antonio TX, 20-23 Oct 1980. The topics include various aspects of aircraft fuels such as availability, conservation, research and development programs, engine design, supply, environmental controls, fuel quality, additives, reclamation, transportation, facilities, systems, and trends for the future. The symposium was hosted by the Directorate of Energy Management, San Antonio Air Logistics Center

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Accession For
A

An Address

By

General Bryce Poe II

Commander, Air Force Logistics Command

to the

Military/Industrial Energy Symposium

in

San Antonio, Texas

on

October 21, 1980

I want to thank General Clark for giving me the opportunity to keynote this very important symposium. As I look around the room I see a great number of people well qualified to discuss the overall subject of energy. As I recall the agenda, many of you will do just that over the next three days.

We all have our opinions on this matter--either professional, personal or both--and our biases are often born of waiting in line for gasoline or scratching our heads when the monthly utility bill arrives.

But the particular bias I want to discuss this morning is that of a professional soldier--as one who will be in the thick of things if this currently tentative international order falls apart.

In terms of an overview, the world was jolted into a new realm of existence by the oil embargo of 1973. With that event and the monumental price rises that followed, a swirl of forces was set into motion that is impacting world events today and most certainly will reshape the international order of the future.

If you are an armchair historian like me, you are inclined to group years and events into eras. It makes for neater bookkeeping and greater understanding. One of the most precise eras of the 20th century (or any century) is bounded by the close of World War II and the oil embargo of 1973.

With the close of the war, American power was at its zenith. The entire world looked to us for leadership and influence. Economic growth--both here and abroad--proceeded at historically high rates. The entire spectrum of human activity became increasingly energy intensive. Technology exploded. World population almost doubled and the number of nation-states more than tripled.

Oil was readily available, cheap and its use encouraged. But the bubble burst in 1973. In a somewhat politically contrived shortfall, the producing Arab states shut off oil exports--dramatizing how dependent we had become not only on oil per se, but on foreign sources of supply.

The blockage was gradually eased and finally lifted in May of 1974, but not without an immediate 400 percent increase in price. The era of cheap oil was over with a thud and another era of accommodation or adjustment had begun.

We are still in that post-embargo period. Our track record has been spotty at best. In the last six years, oil prices have risen by a factor of about 15 but the relative importance of oil has not diminished. Coal and nuclear alternatives remain troubled. Breakthroughs in shale, solar, geothermal and in other alternatives remain elusive. Equally troublesome, certain of our military capabilities require modernization at precisely the time world stability has become far more precarious and less predictable.

As we stand at the beginning of the 1980s, the world is not a safer place to live--largely because of the oil factor. And there are some realities we need to

face. Oil diplomacy has already reshaped what had become the international order of things in previous eras and is likely to create some heretofore strange bedfellows in the future. Secondly, we must pursue energy independence but with sanity and objectivity. Thirdly, we must keep our powder dry. The greatest hedge against future uncertainty remains a strong, flexible defense.

Let's look at the international impact of rising oil prices and restricted supply. Economists the world over have already reevaluated downward their expectations of economic and industrial growth--at least during the first half of this decade. OPEC oil earnings will probably exceed 200 billion dollars this year compared to about 18 billion in 1972. This vast concentration of capital has had a ripple effect throughout the world economy. The resulting impact on production, balance of payments and inflation is inevitable. That means lowered expectations which could lead to political and social strife.

The developing Third World nations are particularly hard hit as deficits mount to meet oil bills and as other nations cut imports. A forthcoming World Bank report will show that the 50 billion dollar oil bill the poor countries in the world will pay this year will double in real terms in the 1980s.

Also, the pressures among our traditional allies could increase. Oil is an economic "life and death" issue and well could prove thicker than tradition. The 1973 embargo demonstrated the powerful influence of diminished oil supplies. Then, the cutback was not absolute since the large multinational oil corporations were free to redirect and redistribute large amounts of oil in transit. With an "actual" shortage in the future, the effect could be much more dramatic.

Adding to the potential pressure among our NATO allies is their uneven distribution of energy resources. The North Sea oil provides Great Britain and Norway a degree of self-sufficiency not enjoyed by the other members. Europe's large, exploitable coal reserves are concentrated in Great Britain and West Germany while the Netherlands has large reserves of natural gas. On the other hand, France, Belgium and Italy can barely supply 25 percent of their energy needs.

Even the Communist bloc is not immune. The Soviets may receive some vicarious pleasure from the plight of the industrialized nations, but they likely will feel the pinch of tighter trade and inflationary pressures.

Most serious, the Soviet Union could be a net importer of oil by the middle of this decade. They have been the world's largest producer for several years followed by the United States and Saudi Arabia. In the first six months of this year, their oil production was running slightly more than 12 million barrels a day--an increase over the 11.7 million average of last year.

But all is not well. They essentially have a production rather than a supply problem. The easily accessible western oil fields and the main Siberian field are being depleted. They now must turn to reserves located in extremely primitive areas east of the Urals and in the northern half of West Siberia.

The costs and logistical problems associated with that undertaking will be staggering. A recent Air University study estimated that roadways in swamp areas could cost the Soviets over 1.6 million dollars per mile. Tractors and other heavy equipment are routinely lost in the marsh while each oil well is a man-made island requiring years to construct. In other regions, the costs are even greater--with roadway expenses approaching three million dollars per mile.

The CIA has predicted Soviet oil production will fall to 9 million barrels a day by 1985--precisely when their in-country and allied demand is increasing. Growing numbers of cars and trucks are being introduced in Soviet society. Agriculture and industry are becoming increasingly energy intensive. Exports to their allies have now grown to an estimated two million barrels per day--largely to Eastern Europe, Mongolia, Vietnam and Cuba.

We do not have an absolute picture of the building oil pressures in the Soviet Union, but there are very clear signs that policies are shifting. Moscow has publicly cautioned its allies to look for alternative energy supplies in the coming years. They have also been very reluctant to make long-term commitments to sell oil. And they have been intensely interested in purchasing Western oil equipment.

But the most ominous indicator is the growing Soviet presence in the Middle East. Apparently, the 1973 embargo was a benchmark of another sort for them, clearly demonstrating the importance of oil to worldwide control. That same year, they flew 832 resupply missions in 14 days during the Arab-Israeli conflict--hauling 13,000 tons of military equipment and supplies to Egypt, Syria and Iraq.

They developed a large naval base in Somalia in 1974, aided the Ethiopian Ogaden campaign in 1977, developed a naval and air facility at Aden, South Yemen, in 1978 and assisted the new military regime in Afghanistan that same year.

Soviet troops are now poised along Iran's northern and eastern borders. A Soviet fleet cruises the Indian Ocean and Arabian Sea. Soviet advisors remain in South Yemen and Ethiopia and Soviet equipment has been stockpiled or situated in Libya and Syria.

They have had a few setbacks. They were asked to leave Somalia in 1977 and their invasion of Afghanistan last December--however alarming to us--indicates a failure of their earlier efforts as well as a blatant display of the geopolitical importance they attach to that part of the world.

To all of this must be added the almost total absence of predictability in the Middle East. Of course another Arab-Israeli conflict can never be ruled out, with almost certain impact on the flow and price of oil.

But short of that worst-case event, we are subject to the whims and caprice of events over which we have little or no control. For example, only a few short weeks ago the press was discussing the glut of oil on the world market. Supplies were building and prices were actually coming down.

Then the Iraq-Iran dispute erupted, shutting off oil exports from both countries. Now, the press is discussing the possibility of gas lines next summer and the continuation of rising prices. Saudi Arabia has indicated they will increase production. But will they? And if so, will the increase be enough to prevent the gas lines or to hold down prices?

In reality, and again I am displaying the bias of a professional soldier, the only trump cards our nation can develop is full energy independence and a strong, flexible defense. And we need to get on with both programs.

As for energy independence, we seem to be making progress. I think we have everybody's attention and the groundwork appears to be getting more firm.

Americans are apparently serious about conservation. After all, it's a pocketbook issue and it hurts. Imports in August were down from last year--from 6.7 to 5.2 million barrels a day. For the first seven months of this year, imports averaged seven million barrels a day, about 41 percent of our total consumption of 17.5 million barrels. A big boost has been the 1.5 million barrels a day we now receive from Alaska. Another boost has been the production and sale of more energy efficient cars. Also, some 11 million Americans have taken advantage during the last two years of tax credits to retrofit their homes. In industry, there has been a steady drop in the ratio of energy input to productive output.

According to the Washington Post, imports have now sunk close to the rate at the trough of the 1975 recession when there were some 20 million fewer cars and trucks on the highways and industrial production was 25 percent lower.

However, the "alternatives" picture remains troubled. And part of the problem is that we still don't have our heads on straight. A classic example is nuclear power. I am not here to champion the cause of nuclear power, but I think more thought and less emotion should characterize the decision making process.

Nuclear power is not a panacea. But it could provide a giant step toward energy independence. Harvard University professors Richard Wilson and Robert Kline both claim we would be importing one-third less oil today had we continued with the 1970 nuclear program. We do know that nuclear plants produce electricity at less than half the cost of oil. They require less land, involve no ugly coal storage or strip mining and result in little air pollution. In short, there are a great number of positive things to be said about nuclear power. But you seldom hear them. What you do hear is the emotional pleas of a small minority. And so far, their attitudes have held sway. They make some valid points on safety and management but let's not turn our backs on nuclear power and expose the nation to the much more dangerous spector of war, even nuclear war, over energy resources.

Another area requiring a more balanced perspective is the impact of environmental concerns on the development of energy sources. The National Review recently published an incredible letter sent by the Bureau of Land Management to an oil company in Colorado. It's a letter that clearly demonstrates the point I am making. Let me read you a portion of it:

"This is in response to your request for a variance regarding the sage grouse strutting-nesting complex stipulations attached to the above mentioned lease and well site. At this time the available data suggest that noise from around-the-clock drilling operations tends to suppress sage grouse strutting activities. Combined with the fact that the proposed lease and well site is located within the nesting habitat associated with two strutting grounds, we feel the variance should not be granted in order to protect the resource. Since there is lack of research data on this problem (noise effects on sage grouse strutting, etc.), the Bureau is proposing a research study to determine these effects. However, because of our planning system and budget requirements, WE DO NOT ANTICIPATE STARTING THE FIELD WORK FOR AT LEAST THREE YEARS . . ."

Fortunately, we are making progess in other areas. The Congress passed an 88 billion dollar synthetic fuels program in June providing federal loan guarantees and other incentives. The goal is to encourage private industry to develop some 500,000 barrels of synthetic fuel a day by 1987 and two million barrels a day by 1992.

In July, the Department of Energy distributed 200 million dollars in awards. Most went to large entities. But about 34 million dollars went to small or minority businesses and to people with good ideas. For example, a company in Talledega County, Alabama, thinks it can produce 40 million gallons of ethanol a year from corn and milo. The Modoc Lumber Company in Klamath Falls, Oregon, proposes to turn its wood biomass residue (what I always called sawdust) into solid fuel.

The point is, the wheels are turning. The progress has been slow and the technological breakthrough we wanted has not come. But the chase is on and we will get there. We have a number of resources to investigate. For example, we have over 220 billion tons of known recoverable coal reserves--the largest in the world and enough to last two or three centuries at current rates of production.

Depending on which source you ask, we have up to two trillion barrels of shale oil reserves with about 600 billion barrels considered to be potentially recoverable. In addition, our tar sand deposits contain between 130 and 200 billion barrels.

We in the military, of course, have a great stake in all of this. DOD is a small but conspicuous user of energy--about two percent of the fuel consumed in the United States. When push comes to shove, we must have ample supplies. For example, an F-15 fighter climbing to 40,000 feet in 1.13 minutes puts out 44,516 horsepower and burns 156 gallons per minute. A 280,000-shaft-horsepower aircraft carrier, such as the JOHN F. KENNEDY, at 33 knots burns 395 gallons per minute. A 750-horsepower M-60 tank cruising at 15 miles per hour burns almost three gallons of fuel per mile.

In terms of petroleum, the Air Force uses 56 percent of DOD"s purchases. Of that, 91 percent goes for aviation fuel.

We have tried to cut that figure. Since FY 73, we have reduced our energy use about 35 percent. Nevertheless, during that same period, fuel costs increased more than 120 percent. Given our current flying hour program of about three million hours a year, when the cost of fuel goes up one cent a gallon, our O&M budget goes up 36 million dollars. And jet fuel has risen considerably since 1973--from 11 cents a gallon to a dollar eighteen.

In early 1978, I directed that AFLC should be free of dependence on fuel oil, natural gas and purchased electricity by the year 2000. I'm pleased with our progress towards that goal.

In the area of research, we have solar energy projects underway at Robins Air Force Base in Georgia and at Wright-Patterson. We are burning refuse derived fuel at Wright-Patt, reusing contaminated JP-4 at Robins and recovering and using waste heat at Wright-Patt.

In the field of JP-4 conservation, several years ago we adapted oil derived from shale and successfully test flew a T-39 jet. The Navy has also done the same thing. In conjunction with Systems Command, we are now planning a shale oil validation program for the 1983-84 timeframe. Our tentative plans are to put the flight operations at two or more tactical bases completely on shale derived fuel should enough synthetic product be available. The availability of this product, however, will depend on how successful the Department of Energy is in obtaining commercialization through the Energy Security Act.

Of course all of this is promising and should eventually lead us out of the energy wilderness. But the requirement for a strong, flexible defense will remain a vital factor in the equation.

And frankly, when we compare our efforts in recent years to the Soviet Union, it is not very reassuring. Since the early 1960s, Soviet defense spending has increased an average of three to four percent a year. They matched us dollar for defense dollar in 1971 and continued to climb.

During the 1970s, they outspent us for military equipment, R&D, and facilities by some 240 billion dollars. With that amount of money, we could have paid for the entire B-1 program--244 aircraft; all currently planned Trident submarines and missiles; the M-X program, including shelters and all supporting systems; about 200 new transport aircraft; the entire planned buy for the modernization of our Air Force and Navy tactical air programs--all F-14s, F-15s, F-16s, F-18s and A-10s. In so doing, we would have modernized all three legs of the strategic triad as well as our tactical forces. With the remainder, we could have funded the increase in pay and allowances for our people and completed all of our backlogged facility upgrade projects. And we still would have had some change left over.

Last year alone, the Soviets outspent us in weapons, equipment, and facilities investment by a staggering 80 percent. As a result, they possess an accumulated

military capital stock 25-30 percent greater than ours. In defense research and development alone they outspent us by 70 billion dollars during the 1970s. In virtually every significant category, they hold numerical advantages and they are quickly closing whatever quality gaps that may exist.

The FY 81 budget is a step--a conservative one--in the right direction. Although we don't have a final Congressional markup, we should see about a five percent real growth.

That trend must continue. I cannot tell you how these worldwide uncertainties and cross currents will evolve. I do not know how the Soviets will use their growing military strength as their supply of oil decreases.

I do know that energy independence must be achieved as quickly as possible. In the interim and thereafter, a strong, flexible defense--equal to any nation and capable of meeting any challenge--is absolutely necessary. The two requirements, energy independence and defense, are inseparable.

Thank you and I hope you have a most successful conference.

U.S. ENERGY OUTLOOK
(INTERIM SYNTHETIC FUELS PROGRAM)

PRESENTED BY

MR. RALPH BAYRER
ACTING DIRECTOR OF INDUSTRIAL ANALYSIS
AND STRATEGY PLANNING—RESOURCE
APPLICATION - DEPARTMENT OF ENERGY

COPY OF SLIDES ONLY - SCRIPT NOT AVAILABLE

INDUSTRY-MILITARY ENERGY SYMPOSIUM
SAN ANTONIO, TEXAS
OCTOBER 21-23, 1980

- PL96-294, "ENERGY SECURITY ACT," JUNE 30, 1980

  TITLE I, PART A - AMENDED DEFENSE PRODUCTION ACT FOR SYNTHETIC FUELS

  PART B - CREATED U.S. SYNTHETIC FUELS CORPORATION
  AUTHORIZED $20 BILLION ENERGY SECURITY RESERVE TO RESIDE IN THE DEPARTMENT OF TREASURY

- PL96-126, "DEPARTMENT OF THE INTERIOR AND RELATED AGENCIES APPROPRIATIONS FOR FISCAL YEAR 1980," NOVEMBER 27, 1979

  APPROPRIATED $2.208 BILLION FROM ENERGY SECURITY RESERVE TO DOE TO BE USED UNDER THE AUTHORITIES OF PL93-577, "FEDERAL NONNUCLEAR RESEARCH AND DEVELOPMENT ACT OF 1974"

- PL96-304, "FY 80 SUPPLEMENTAL APPROPRIATIONS," JULY 2, 1980

  APPROPRIATED $3.310 BILLION TO DOE TO BE USED UNDER AUTHORITIES OF DEFENSE PRODUCTION ACT AMENDMENTS ABOVE

RELEVANT LEGISLATION - SYNTHETIC FUELS

NONNUCLEAR ACT

GASEOUS, LIQUID OR SOLID FUELS & CHEMICAL FEEDSTOCKS DERIVED FROM THE FOLLOWING DOMESTIC RESOURCES:

- COAL
- OIL SHALE
- TAR SANDS
- HEAVY OIL
- UNCONVENTIONAL NATURAL GAS
- LIGNITE
- PEAT
- OTHER MINERALS OR ORGANIC MATERIALS

DPA AND U.S. SYNFUELS CORPORATION

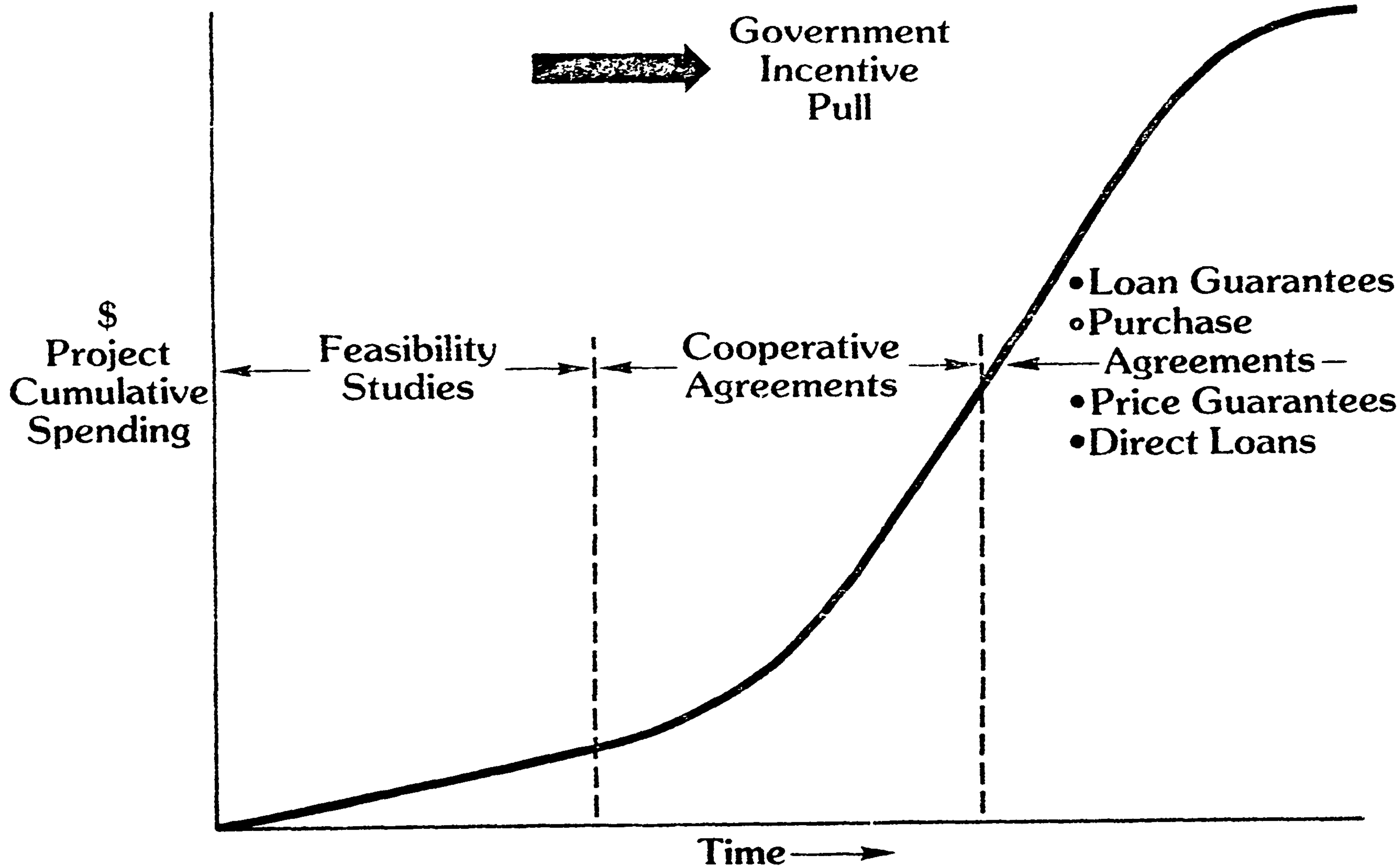
ANY SOLID, LIQUID OR GAS OR COMBINATION THEREOF, WHICH CAN BE USED AS A SUBSTITUTE FOR PETROLEUM OR NATURAL GAS (OR ANY DERIVATIVES THEREOF, INCLUDING CHEMICAL FEEDSTOCKS) AND WHICH IS PRODUCED BY CHEMICAL OR PHYSICAL TRANSFORMATION (OTHER THAN WASHING, COKING OR DESULFURIZING) OF DOMESTIC RESOURCES OF:

- COAL, INCLUDING LIGNITE AND PEAT
- SHALE
- TAR SANDS, INCLUDING CERTAIN HEAVY OILS
- WATER, AS A SOURCE OF HYDROGEN THROUGH ELECTROLYSIS
- COAL/COMBUSTIBLE LIQUID MIXTURES, INCLUDING PETROLEUM
- DIRECT BURNING OF URBAN WASTE*
- HEAVY OILS

*CATEGORY INCLUDED IN ERROR; INTENTION TO REMOVE IN FUTURE.

\- TECHNOLOGIES/PROJECTS ELIGIBLE FOR GOVERNMENT ASSISTANCE -

Basic Strategy for Government Incentive Application



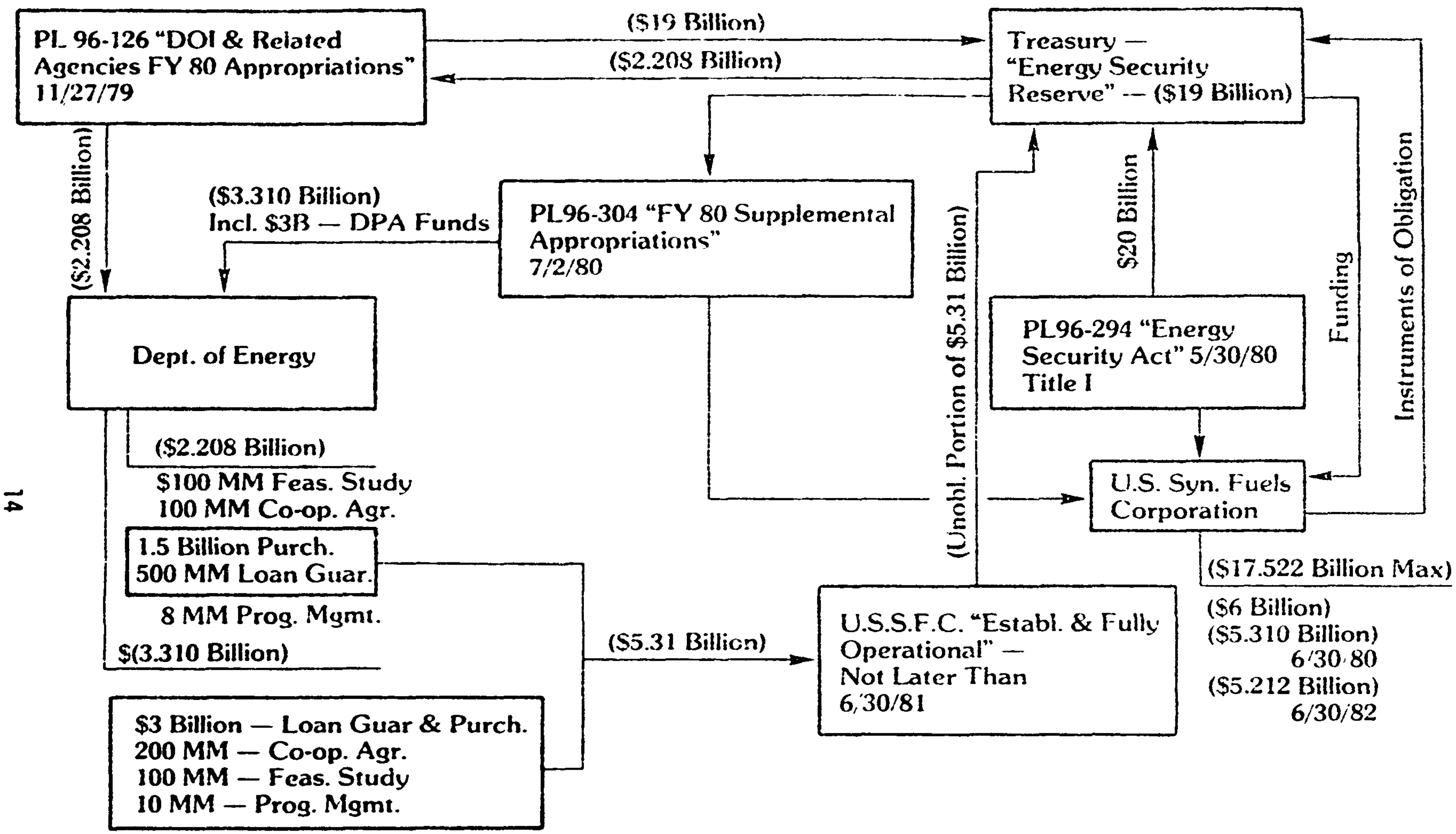
ASSISTANCE CATEGORY	NONNUCLEAR R&D ACT $2.208 BILLION	DEFENSE PROD. ACT $3.310 BILLION
• FEASIBILITY STUDIES	$100MM @$4MM MAX.	$100MM @ $10MM MAX.
• COOPERATIVE AGREEMENTS	$100MM @$25MM MAX.	$200MM @ $25MM MAX.
• PURCHASE AGREEMENTS, PRICE GUARANTEES, PURCHASES	$1.5 BILLION	$3 BILLION - PURCHASE COMMIT., PRICE GUARANTEE - LOAN GUARANTEE (2) RESERVE AGAINST LOAN VALUE @1:1
• LOAN GUARANTEES	$500MM RESERVE @ 3:1 AGAINST $1.5 BILLION LOANS (1)	
• PROGRAM MANAGEMENT	$8MM	$10MM

NOTES:

(1) DOE LOAN GUARANTEE REGULATIONS APPLY TO THESE LOANS; DO NOT APPLY TO DEFENSE PRODUCTION ACT LOAN GUARANTEE AUTHORITIES.

(2) DPA LOAN GUARANTEE LIMITED TO $38MM MAXIMUM PER LOAN

ALLOCATION OF APPROPRIATED FUNDS



Funding Flows Among DOE, the Energy Security Reserve & the U.S. Synthetic Fuels Corp.

AN ENERGY CHOICE

PRESENTATION BY

FRED L. HARTLEY
CHAIRMAN AND PRESIDENT
UNION OIL COMPANY OF CALIFORNIA
AND
CHAIRMAN, AMERICAN PETROLEUM INSTITUTE

TO THE

DEPARTMENT OF THE AIR FORCE
DIRECTORATE OF ENERGY MANAGEMENT
SAN ANTONIO AIR LOGISTICS CENTER
SAN ANTONIO, TEXAS

OCTOBER 21, 1980

THANK YOU, GENERAL CLARK.

I AM HONORED TO HAVE THE OPPORTUNITY TO PARTICIPATE IN THIS SYMPOSIUM ON ENERGY MANAGEMENT AND TO PROVIDE YOU WITH SOME POSITIVE THOUGHTS ON AMERICA'S ENERGY OUTLOOK.

ENERGY IS A MOST CRITICAL ELEMENT IN AMERICA'S NATIONAL SECURITY, INVOLVING MORE THAN JUST OUR OWN COUNTRY'S FIGHTING CAPABILITY. IT SERIOUSLY AFFECTS THE FLEXIBILITY OF OUR TOTAL FOREIGN POLICY AS WELL AS THE ECONOMIC AND MILITARY VIABILITY OF OUR ALLIES.

SECURE ENERGY SUPPLIES ARE ESSENTIAL TO OUR ECONOMIC AND MILITARY STRENGTH. AS PRESIDENT CARTER HAS SAID, "OUR COUNTRY IS AT ONE END OF A 12 THOUSAND-MILE SUPPLY LINE AND HALF THE OIL THAT WE USE IS ON THE OTHER END OF THAT SUPPLY LINE. ENERGY SECURITY IS A VITAL LINK BETWEEN NATIONAL MILITARY SECURITY ON THE ONE HAND AND ECONOMIC SECURITY AT HOME."

THE UNITED STATES' ABILITY TO CONDUCT ITS FOREIGN AFFAIRS HAS BEEN HAMPERED BECAUSE OF THE UNRELIABILITY OF OUR OIL SUPPLIES. THE CONCENTRATION OF OIL DEPOSITS IN THE PERSIAN GULF AREA LAYS THE NATION OPEN TO RISKS: THE RISK OF INTERDICTION OR EVEN THE RISK OF NATURAL OR ACCIDENTAL DISTURBANCES.

CLEARLY, REDUCED ENERGY DEPENDENCE WOULD GIVE US ADDITIONAL OPTIONS TO ENHANCE OUR NATIONAL SECURITY.

IF WE CONTINUE ON OUR PRESENT COURSE, HOWEVER, OUR WORLD IN 1990 WILL OFFER FEWER SECURITY OPTIONS AND LESS ENERGY FLEXIBILITY.

FORTUNATELY, WE HAVE A CHOICE--A REAL ONE. WITH A REASONABLE CHANGE IN GOVERNMENT POLICY AND PUBLIC ATTITUDES, WE CAN REDUCE OUR DEPENDENCE ON ENERGY SUPPLIES FROM INSECURE AREAS OF THE WORLD. WE CAN SLOW DOWN O.P.E.C.'S ABILITY TO RAISE PRICES. AND WE CAN PROVIDE FOR GREATER NATIONAL SECURITY THROUGH A STRONGER ECONOMY.

IT CAN BE DONE WITH RELATIVELY MODEST CHANGES, CHANGES WHICH ALTER UNBALANCED ENVIRONMENTAL LAW, BUT DO NOT ROLL BACK ENVIRONMENTAL PROGRESS; CHANGES WHICH PERMIT ACCESS TO PUBLIC LANDS WHERE MAJOR ENERGY RESOURCES LIE BUT STILL PRESERVE THE BEST OF THE WILDERNESS AREAS; CHANGES THAT ALLOW GREATER USE OF COAL AND NUCLEAR POWER BUT DO NOT SACRIFICE HEALTH AND SAFETY.

HOW IS THIS POSSIBLE?

WELL, WE OFTEN FORGET--OR PERHAPS ARE UNAWARE--THAT WHILE WE IMPORT NEARLY HALF OF OUR OIL, WE PRODUCE ABOUT EIGHTY PERCENT OF OUR TOTAL ENERGY. BY 1990 WE WANT TO INSURE THAT WE ARE PRODUCING NINETY PERCENT OF OUR ENERGY AND NOT SEVENTY PERCENT

THANKS TO MOTHER NATURE, AMERICANS CAN CHOOSE TO ACHIEVE A HIGH DEGREE OF ENERGY SELF-SUFFICIENCY IN A COMPARATIVELY SHORT TIME. FEW OTHER COUNTRIES HAVE THAT OPTION. WE CAN REDUCE OUR IMPORTS OF OIL AND MATERIALLY LOWER OUR DEPENDENCE ON UNCERTAIN AND POTENTIALLY HOSTILE SOURCES.

IF WE KEEP OIL IMPORTS AT TODAY'S LEVELS, THE UNITED STATES WILL STILL NEED MORE DOMESTIC ENERGY TO PROVIDE FOR THIS GROWTH. IF WE WANT TO REDUCE TODAY'S IMPORTS--WHICH IS OUR ULTIMATE AIM--WE'LL NEED EVEN MORE DOMESTIC ENERGY TO REPLACE FOREIGN OIL.

WE HAVE ENOUGH RESOURCES AVAILABLE IN OUR COUNTRY TO MEET THIS GROWTH IN ENERGY DEMAND AND AT THE SAME TIME TO MATERIALLY REDUCE OIL IMPORTS. GIVEN THE RIGHT CLIMATE, WE HAVE SUFFICIENT OIL, NATURAL GAS, COAL, NUCLEAR POWER AND GEOTHERMAL ENERGY AVAILABLE WITHIN OUR OWN BORDERS WHICH COULD CARRY US UNTIL SYNTHETIC FUELS OR EVEN SOLAR POWER AND OTHER NON-TRADITIONAL ENERGY FORMS ARE DEVELOPED.

THESE ARE THE THINGS WE AS A NATION CAN DO WITHIN THE NEXT DECADE OR SO:

-- WE CAN STOP THE DECLINE IN U.S. OIL PRODUCTION.

-- WE CAN MAINTAIN OR INCREASE OUR NATURAL GAS PRODUCTION.

-- WE CAN ABOUT DOUBLE COAL CONSUMPTION.

-- WE CAN TRIPLE ENERGY SUPPLIED BY NUCLEAR POWER.

-- WE CAN INCREASE PRODUCTION FROM SYNTHETIC FUELS AND RENEWABLE SOURCES OF ENERGY, INCLUDING BIOMASS IN ITS MANY FORMS.

I SAY AGAIN: THESE THE THINGS WE CAN DO. WHETHER WE AS A NATION WILL ACHIEVE THESE GOALS REMAINS TO BE SEEN. ACCOMPLISHMENT WILL REQUIRE SOME POSITIVE GOVERNMENT ACTIONS.

FIRST, WE NEED CONSISTENCY IN GOVERNMENT POLICIES TOWARD ENERGY USERS AND ENERGY PRODUCERS.

A FEW YEARS AGO, FOR EXAMPLE, THE FEDERAL GOVERNMENT ENCOURAGED ENERGY-USING INDUSTRIES AND UTILITIES TO SWITCH FROM PLENTIFUL BUT POLLUTING COAL TO CLEAN NATURAL GAS. THEN THEY WERE ASKED TO CHANGE FROM CLEAN BUT SCARCE NATURAL GAS TO OIL. NOW THEY'RE BEING URGED TO CHANGE FROM OIL BACK TO COAL AND NATURAL GAS. HOPEFULLY, THE LATTER IS ONLY TEMPORARY. ALL OF THESE CHANGES ARE COSTLY AND ENERGY USERS NEED TO GET OFF THIS MERRY-GO-ROUND.

SECOND, WE NEED A BETTER BALANCE BETWEEN ENERGY AND ENVIRONMENTAL GOALS, RECOGNIZING THAT EACH HAS A LEGITIMATE ROLE. CONGRESS AND THE ADMINISTRATION HAVE CREATED A WEB OF AT LEAST THIRTEEN BASIC FEDERAL ENVIRONMENTAL LAWS OF UNPRECEDENTED COMPLEXITY. THESE LAWS, AND THE TENS OF THOUSANDS OF PAGES OF REGULATIONS STEMMING FROM THEM, BOGGLE THE MINDS OF PEOPLE IN THE REGULATORY AGENCIES AS WELL AS PEOPLE IN THE ENERGY AND OTHER AFFECTED INDUSTRIES. DESPITE HERCULEAN EFFORTS BY THE REGULATORS AND REGULATED ALIKE, THE PERMITTING PROCESS IS SLOW AT BEST, AND UNWORKABLE AT WORST. FOR EXAMPLE, TO DRILL AN EXPLORATORY WELL IN ALASKA, UNION OIL MUST OBTAIN THIRTY-SEVEN STATE PERMITS OR LICENSES, NINETEEN FEDERAL PERMITS OR LICENSES, FIVE AGENCY OR COMMISSION PERMITS, AND AN UNKNOWN NUMBER OF LOCAL GOVERNMENT LICENSES OR PERMITS. THE TIME REQUIRED IS INTERMINABLE.

THE BASIC QUESTION IS NOT WHETHER ENVIRONMENTAL REGULATION IS NECESSARY AND WISE. THE BASIC QUESTION IS HOW TO REGULATE WISELY.

WISE REGULATION SHOULD INCLUDE REVIEW AND MODIFICATION OF EXISTING ENVIRONMENTAL STANDARDS, FLEXIBLE RULES, SIMPLIFIED PERMITTING PROCESSES, ANALYSES OF COSTS AND BENEFITS, BETTER COORDINATION OF FEDERAL, STATE AND LOCAL REGULATION, AND INNOVATIVE POLLUTION CONTROL CONCEPTS.

THIRD, WE NEED GREATER RELIANCE ON THE MARKET SYSTEM TO DO THE JOB. MARKET FORCES IN THE PAST FEW MONTHS HAVE ACCOMPLISHED MORE THAN YEARS OF INSPIRATIONAL MESSAGES ABOUT VOLUNTARY CONSERVATION. AMERICANS ARE LEARNING TO SAVE ENERGY BECAUSE THEY WANT TO SAVE MONEY. THE SHARP PRICE INCREASES OF LAST YEAR HAVE HAD MORE IMPACT THAN ALL THE GOVERNMENT PROGRAMS AND ORATORY, CHALLENGES AND PLEADINGS FOR CONSERVATION OF THE LAST FIVE YEARS.

AS A RESULT, WE ARE USING ABOUT TEN PERCENT LESS OIL THIS YEAR THAN LAST.

THE RELATIONSHIP BETWEEN GNP GROWTH AND ENERGY GROWTH HAS ALTERED SHARPLY AND THE PROJECTIONS OF TOTAL ENERGY USE IN THE UNITED STATES FOR 1990 HAVE PLUMMETED.

WE NOW EXPECT TO REQUIRE ONLY ABOUT TEN PERCENT MORE ENERGY IN ALL FORMS IN 1990 THAN WE USED LAST YEAR. BUT THE PROBLEM IS STILL TO PRODUCE THAT EXTRA TEN PERCENT DOMESTICALLY, AND SIMULTANEOUSLY REDUCE IMPORTS.

THE ALTERNATIVES TO MARKET FORCES THAT HAVE BEEN TRIED--PRICE CONTROLS AND ALLOCATION CONTROLS--HAVE NOT WORKED. PRICE CONTROLS HAVE CONTRIBUTED TO THE DECLINE IN U.S. OIL AND GAS PRODUCTION. THE FEDERAL ALLOCATION SYSTEM WAS CHIEFLY RESPONSIBLE FOR TURNING LAST YEAR'S SLIGHT IMPORT SHORTFALL INTO LONG GASOLINE LINES IN MANY PLACES.

FOURTH, WE NEED TO ALLOW GREATER ENERGY EXPLORATION ON PUBLIC LANDS AND OFFSHORE AREAS. THE MOST PROMISING PROSPECTS FOR NEW SUPPLIES OF U.S. ENERGY ARE FEDERAL LANDS.

THE FEDERAL GOVERNMENT CONTROLS ABOUT ONE-THIRD OF ALL THE LAND IN THIS COUNTRY AND ALL OF THE OUTER CONTINENTAL SHELF BEYOND STATE JURISDICTION. YET, TODAY, ONLY ABOUT ONE-THIRD OF ALL ONSHORE PUBLIC LANDS AND LESS THAN FIVE PERCENT OF THE OUTER CONTINENTAL SHELF HAVE BEEN OPENED FOR ENERGY DEVELOPMENT.

GOVERNMENT LANDS, INCLUDING THE OUTER CONTINENTAL SHELF, NOW PROVIDE SIXTEEN PERCENT OF U.S. PRODUCTION OF OIL AND NATURAL GAS LIQUIDS. BUT GOVERNMENT STUDIES INDICATE THAT THESE LANDS CONTAIN THIRTY-SEVEN PERCENT OF OUR UNDISCOVERED OIL RESOURCES.

GOVERNMENT LANDS PROVIDE THIRTY PERCENT OF THE NATION'S NATURAL GAS OUTPUT. BUT STUDIES SHOW THAT FORTY-THREE PERCENT OF OUR UNDISCOVERED NATURAL GAS RESOURCES LIE ON THESE LANDS.

GOVERNMENT LANDS PROVIDE ONLY EIGHT PERCENT OF TODAY'S COAL PRODUCTION. BUT THEY HOLD FORTY PERCENT OF THE NATION'S REMAINING COAL SUPPLIES.

MOST OF THE MAJOR LAWS THAT REGULATE ENERGY PRODUCTION ON FEDERAL LANDS TODAY WERE PASSED IN THE LAST TEN YEARS. WHILE EACH WAS INTENDED FOR ONE PARTICULAR PURPOSE, TOGETHER THEY HAVE CREATED REGULATIONS WHICH UNNECESSARILY--AND OFTEN UNINTENTIONALLY--WORK TOGETHER TO HOLD BACK ENERGY DEVELOPMENT.

SAFE AND SUCCESSFUL ENERGY PRODUCTION IN FRAGILE AREAS SUCH AS ALASKA AND THE GULF OF MEXICO HAS SHOWN THAT ACHIEVING ENERGY SECURITY AND PRESERVING OUR NATURAL HERITAGE ARE COMPATIBLE GOALS.

FIFTH, WE NEED TO INCLUDE COAL AND NUCLEAR POWER AS ESSENTIAL COMPONENTS OF OUR ENERGY MIX. COAL IS THE DOMINANT ENERGY RESOURCE IN THE U.S. WITH SUPPLIES ADEQUATE FOR HUNDREDS OF YEARS AT CURRENT RATES OF CONSUMPTION. ITS DEVELOPMENT IS STYMIED BY CHANGING RULES AND PROCEDURES, CHIEFLY STEMMING FROM ENVIRONMENTAL RULE INTERPRETATIONS WHICH I MENTIONED EARLIER.

SOME SEVENTY NUCLEAR POWER PLANTS NOW SUPPLY ABOUT THIRTEEN PERCENT OF U.S. ELECTRICAL REQUIREMENTS. IF ALL ONE HUNDRED AND TEN NUCLEAR POWER PLANTS CURRENTLY UNDER CONSTRUCTION OR ON ORDER ARE COMPLETED DURING THIS DECADE, THE NUCLEAR CONTRIBUTION TO THE NATION'S ENERGY WOULD ABOUT TRIPLE--TO THE EQUIVALENT OF ABOUT FOUR MILLION BARRELS OF OIL PER DAY. THIS IS A REALISTIC ACHIEVEMENT WHICH CAN BE MET IF CURRENTLY COMPLETED NUCLEAR PLANTS ARE IN OPERATION SOON AND IF PLANTS WITH CONSTRUCTION PERMITS ARE COMPLETED AS SCHEDULED. AND IT CAN BE ACHIEVED WITHIN THE FRAMEWORK OF NEW SAFEGUARDS DEVELOPED AFTER THREE MILE ISLAND.

NUCLEAR POWER, UNFORTUNATELY, HAS BEEN THE VICTIM OF EMOTIONALISM THAT OFTTIMES VERGES ON HYSTERIA.

THE USE OF NUCLEAR POWER MUST HAVE CALM, UNBIASED REVIEW. WITHOUT NUCLEAR POWER, I BELIEVE WE CANNOT MEET OUR ENERGY OBJECTIVES.

MY LAST POINT HAS TO DO WITH ENERGY CONSERVATION, OR AS I PREFER TO CALL IT, ENERGY EFFICIENCY. THIS IS THE ROLE WHICH EACH INDIVIDUAL AMERICAN MUST PLAY TO THE FULLEST MEASURE. AFTER ALL, A BARREL OF OIL SAVED IS AS GOOD OR BETTER THAN A BARREL OF OIL PRODUCED, AND IT HAS NO DECLINE CURVE. THE CURRENT DILEMMA OF DETROIT AUTOMAKERS DEMONSTRATES THAT THE AMERICAN PEOPLE WANT ENERGY EFFICIENCY.

WHY AM I STRESSING WHAT CAN BE DONE TO INCREASE OUR ENERGY SELF-SUFFICIENCY? FIRST, BECAUSE IT IS AN ATTAINABLE GOAL ESSENTIAL TO THIS COUNTRY'S GROWTH AND PROSPERITY--AND PROBABLY OUR VERY EXISTENCE. SECOND, BECAUSE THE AMERICAN PEOPLE ARE TIRED OF DOOMSAYERS. THEY WANT ENCOURAGEMENT. THEY WANT TO HAVE A CHOICE. THEY <u>CAN</u> HAVE A CHOICE.

THE DECISION BETWEEN ENERGY SECURITY OR CONTINUED ENERGY DEPENDENCY DEPENDS ON ALL AMERICANS.

WITH SOME CHANGES IN GOVERNMENT POLICIES--AND ADJUSTMENTS IN THE LAWS AND RULES THAT REFLECT THESE POLICIES--THIS NATION CAN WIN BACK MOST OF THE CONTROL OVER ITS ENERGY AFFAIRS THAT WAS LOST WHEN IMPORTS JUMPED DRAMATICALLY DURING THE 1970'S.

LET ME REVIEW. REGULATORY CONSISTENCY, ENVIRONMENTAL BALANCE, RELIANCE ON MARKET FORCES, ACCESS TO PUBLIC LANDS, A FORTHRIGHT PROGRAM FOR NUCLEAR AND COAL UTILIZATION, AND VIGOROUS ADHERENCE TO ENERGY EFFICIENCY--THESE ARE ESSENTIAL PARTS OF A POSITIVE AND FEASIBLE PROGRAM TO INCREASE OUR ENERGY SELF-SUFFICIENCY AND BOLSTER OUR NATIONAL SECURITY BY THE TURN OF THE CENTURY. DURING THIS TIME WE ALSO CAN MAKE MEANINGFUL STRIDES IN THE PRODUCTION OF SYNTHETIC FUELS.

ONE OF THEM--AND THE MOST PROMISING--IS OIL SHALE, AN ENERGY SOURCE WHOSE TIME HAS COME AND IN WHOSE DEVELOPMENT I HAVE BEEN INVOLVED FOR SOME THIRTY YEARS.

ALTHOUGH IT IS FOUND IN MANY LOCATIONS THROUGHOUT THE WORLD, NORTH AMERICA HAS THE MOST FAVORABLE CONCENTRATIONS. THE WORLD'S LARGEST KNOWN DEPOSIT, THE SIXTEEN THOUSAND SQUARE MILE GREEN RIVER FORMATION IN COLORADO, WYOMING, AND UTAH HAS OIL SHALE STRATA UP TO TWO THOUSAND FEET THICK.

THE U.S. DEPARTMENT OF INTERIOR ESTIMATES THIS FORMATION CONTAINS THE EQUIVALENT OF 1.8 TRILLION BARRELS OF SHALE OIL, WITH SOME SIX HUNDRED BILLION BARRELS BEING READILY RECOVERABLE BY TECHNOLOGY NOW IN VARIOUS STAGES OF DEVELOPMENT. THIS SIX HUNDRED BILLION BARRELS IS ABOUT THE SAME AS TOTAL WORLDWIDE PROVED RESERVES OF CONVENTIONAL CRUDE OIL, AND IS OVER TWENTY TIMES THE UNITED STATES' PRESENTLY PROVED CRUDE OIL RESERVES. IT COULD SUPPLY THE EQUIVALENT OF THE NATION'S TOTAL HYDROCARBON CONSUMPTION FOR NEARLY NINETY YEARS.

LET ME NOW EXAMINE IN SOME DETAIL THE NUMBER ONE CHOICE WE HAVE FOR SUPPLYING HYDROCARBON FUELS SYNTHETICALLY.

TO REPEAT, THE OIL SHALE RESOURCES IN THE UNITED STATES AND ON A WORLDWIDE BASIS ARE VERY LARGE. THERE IS NO EXPLORATION RISK SINCE THESE RESERVES ARE WELL KNOWN. IN ADDITION, OIL SHALE IS A RESOURCE WHICH WILL BE USED DOMESTICALLY AND DOES NOT BEAR THE POLITICAL OR SECURITY RISKS ASSOCIATED WITH FOREIGN PRODUCTION.

THE QUALITY OF LIQUID HYDROCARBONS DERIVED FROM OIL SHALE IS MORE COMPARABLE TO CONVENTIONAL CRUDE OIL THAN LIQUIDS FROM COAL. THIS CAN BE SEEN IN TABLE 1. SLIDE I

AFTER ADDING ONE THOUSAND THREE HUNDRED AND FIFTY CUBIC FEET PER BARREL OF HYDROGEN TO SHALE OIL, A SYNCRUDE IS PRODUCED WITH A CARBON-HYDROGEN RATIO SIMILAR TO ARABIAN CRUDE, ABOUT 6.5. EVEN AFTER ADDING SIX THOUSAND CUBIC FEET PER BARREL OF HYDROGEN TO COAL, THE SYNCRUDE HAS A CARBON HYDROGEN RATIO OF ONLY 8.1. THE IMPORTANCE OF THIS IS REALIZED DURING SUBSEQUENT PROCESSING TO PRODUCE HEATING OIL AND GASOLINE WHICH HAVE APPROXIMATE CARBON-HYDROGEN RATIOS OF 6.7 AND 5.8. TRANSPORTATION FUELS PRODUCED FROM SHALE OIL ARE OF EXCELLENT QUALITY, LOW IN SULFUR AND NITROGEN AND WITH SUPERIOR BURNING CHARACTERISTICS.

HISTORY OFTEN REPEATS ITSELF. YOU WILL BE INTERESTED TO KNOW THAT BACK IN 1958 WE OPERATED A SHALE OIL DEMONSTRATION PLANT IN COLORADO WHICH PRODUCED EIGHT HUNDRED BARRELS OF RAW SHALE OIL PER DAY. HERE IS A PICTURE OF THAT PLANT. SLIDE II

PART OF THE PRODUCTION SUBSEQUENTLY WAS COKED AND HYDROPROCESSED INTO JET AND DIESEL FUELS IN THE LABORATORY.

BARREL QUANTITIES OF MILITARY GRADE JP-4 JET FUEL AND MARINE DIESEL FUEL WERE PRODUCED AND SENT TO THE U.S. NAVAL BASE IN PHILADELPHIA AND TO THE U.S. NAVAL ENGINEERING EXPERIMENT STATION AT ANNAPOLIS. IN THE NAVY EVALUATIONS, BOTH FUELS MET ALL MILITARY SPECIFICATIONS AND WERE ADJUDGED SATISFACTORY FOR USE. REMEMBER, ALL OF THIS HAPPENED TWENTY-ONE YEARS AGO.

I WOULD NOW LIKE TO COMMENT IN GENERAL TERMS ON THE POTENTIAL RATE AND MAGNITUDE OF DEVELOPMENT OF A UNITED STATES OIL SHALE INDUSTRY.

THE FIRST MAJOR FACTOR TO BE CONSIDERED IS THE CAPITAL REQUIRED TO PRODUCE OIL FROM SHALE. COMPANIES CONSIDERING SUCH AN INVESTMENT WILL FIND THE CAPITAL COST FOR A FIFTY THOUSAND BARREL PER DAY PRODUCTION PLANT, INCLUDING FACILITIES TO UPGRADE THE SHALE OIL TO A QUALITY USABLE IN EXISTING REFINERY SYSTEMS, WILL BE IN THE ORDER OF TWO BILLION 1980 DOLLARS. THIS EQUATES TO ABOUT FORTY THOUSAND DOLLARS PER DAILY BARREL OF OIL PRODUCTION.

HOWEVER, THE LIFE OF THIS FACILITY WILL BE ABOUT FOUR TIMES THAT OF A CONVENTIONAL OIL PRODUCTION FACILITY COSTING AN AVERAGE OF TEN THOUSAND DOLLARS PER DAILY BARREL IN SOME OF THE MORE DIFFICULT OIL FRONTIERS IN WHICH WE NOW OPERATE. SO, THE TOTAL CAPITAL REQUIREMENTS ARE NOT GREATLY DIFFERENT THAN REQUIRED FOR DEVELOPING SUSTAINED OIL FIELD PRODUCTION ASSUMING YOUR EXPLORATION SUCCESS REPEATS ITSELF THREE MORE TIMES.

WHILE THE RATE OF RETURN ON AN OIL SHALE INVESTMENT WILL BE LESS THAN FOR CONVENTIONAL OIL PRODUCTION, AS TYPICALLY CALCULATED, THE OIL SHALE PLANT WILL PRODUCE AT A UNIFORM DAILY RATE FOR A PERIOD OF TWENTY-FIVE TO THIRTY-FIVE YEARS. A NEWLY FOUND OIL FIELD WILL START ITS DECLINE ALMOST IMMEDIATELY AFTER IT COMES ON PRODUCTION. VIEWED IN THIS LIGHT, THE INVESTMENT IN AN OIL SHALE PLANT IS IN EFFECT A HEDGE AGAINST INFLATION AND SHOULD BE FOUND TO BE ACCEPTABLE EVEN AT THE SOMEWHAT LOWER RATE OF RETURN.

A SECOND MAJOR FINANCIAL PROBLEM IS CAPITAL FORMATION. FOR ALL EXCEPT THE LARGEST COMPANIES, MAKING TWO BILLION 1980 DOLLARS AVAILABLE OVER A REASONABLE TIME SPAN OF SAY FIVE TO EIGHT YEARS WILL SEVERELY TAX THE CAPITAL RESOURCES AVAILABLE TO THE COMPANY. GOVERNMENT CAN AND SHOULD AID THE GENERATION OF CAPITAL BY MEANS OF ACCELERATED DEPRECIATION, INVESTMENT TAX CREDITS, LOAN GUARANTEES, OR PRODUCT PURCHASE AGREEMENTS, INCLUDING ADVANCED PAYMENTS. THE EXTENT TO WHICH THIS ASSISTANCE IS PROVIDED WILL HAVE A MAJOR IMPACT ON THE RATE OF DEVELOPMENT. WITH THE RECENT REQUEST FOR "FAST TRACK" PROPOSALS BY THE DEPARTMENT OF ENERGY, WE COULD BE IMPLEMENTING SHALE OIL PLANTS IN THE VERY NEAR FUTURE.

THE THIRD MAJOR LIMITING FACTOR WILL BE THE ENVIRONMENTAL IMPACT AND THE DEGREE OF COMPROMISE ACCEPTABLE BETWEEN ENVIRONMENTAL PROTECTION AND ENERGY PRODUCTION. THE MOST SERIOUS IMPACT OF SHALE OIL PRODUCTION IS THE DISPOSAL OF RETORTED SHALE. THE RESIDUE FROM RETORTING MUST BE DISPOSED OF CHIEFLY ON THE SURFACE WHICH OBVIOUSLY WILL CHANGE THE CONTOUR OF THE LAND.

IT HAS BEEN DEMONSTRATED THAT RETORTED SHALE CAN BE REVEGETATED AND RESTORED TO A LEVEL OF PRODUCTIVITY COMPARABLE TO THE NATIVE SOIL. IT WILL BE NECESSARY, HOWEVER, TO TOLERATE SOME CHANGE IN LAND CONTOUR.

CONTAMINATION OF THE ATMOSPHERE WILL BE NO MORE SEVERE THAN ANY OTHER FOSSIL FUEL OPERATION SUCH AS ELECTRICAL POWER GENERATION OR PETROLEUM REFINING.

WATER AVAILABILITY IS ANOTHER CONCERN. OIL SHALE SEEMS TO OCCUR IN ARID AREAS IN WHICH WATER FOR SHALE OIL PRODUCTION MUST EITHER BE MADE AVAILABLE PREFERENTIALLY OR SUPPLEMENTARY WATER SUPPLIES MUST BE MADE AVAILABLE BY INTER-BASIN TRANSPORT OR OTHER MEANS.

ALL OF THESE ENVIRONMENTAL PROBLEMS EVENTUALLY WILL BE COMPROMISED AND THE RATE AND AMOUNT OF COMPROMISE WILL LARGELY GOVERN THE SIZE AND RATEABILITY OF THE OIL SHALE INDUSTRY.

FORECASTING AVAILABILITY OF OIL FROM SHALE IS VERY SPECULATIVE AND WILL CONTINUE TO BE UNTIL THE PIONEER PLANTS ARE BUILT AND THE ANSWERS TO SOME OF THE FOREGOING PROBLEMS HAVE BEEN DETERMINED.

IN THE UNITED STATES, SPEAKING OF THE GREEN RIVER FORMATION ALONE, THERE SEEMS TO BE A CONSENSUS THAT BY 1990 PRODUCTION OF FOUR HUNDRED THOUSAND TO FIVE HUNDRED THOUSAND BARRELS PER DAY OF OIL FROM SHALE IS FEASIBLE AND THAT TWO MILLION BARRELS PER DAY MAY BE IN PRODUCTION BY THE YEAR 2000.

PRODUCTION FROM OIL SHALE IN OTHER AREAS AND OTHER COUNTRIES CAN BE EXPECTED. MAJOR PROJECTS HAVE BEEN ANNOUNCED IN BRAZIL AND IN AUSTRALIA AND WORK IS IN PROGRESS IN A NUMBER OF OTHER COUNTRIES.

SLIDE III SHOWS A FLOW SHEET OF THE UNION OIL RETORT PROCESS WE WILL CONSTRUCT ON OUR PROPERTY IN COLORADO, WHICH IS SHOWN IN SLIDE IV.

<u>SLIDE III</u>

<u>SLIDE IV</u>

IT DIFFERS FROM OTHER PROCESSES IN THAT WE PUMP THE SHALE UPWARD SO THAT THE OIL CAN FLOW DOWNWARD BY GRAVITY. AS PREVIOUSLY STATED, WE OPERATED A SIMILAR PROCESS IN THE LATE 1950'S AT RATES UP TO TWELVE HUNDRED TONS PER DAY. HOWEVER, THE INFLUX OF LOW-PRICED MIDDLE EAST CRUDE MADE THE PROJECT UNATTRACTIVE. OF COURSE, THAT SITUATION HAS CHANGED DRAMATICALLY SINCE 1973.

SLIDE V IS AN ARTIST'S CONCEPTION OF THE PROPOSED RETORT MINE AND SLIDE VI IS THE RETORT INSTALLATION. SLIDE V SLIDE VI

THE PLANT WILL BE LOCATED AT THE MINE MOUTH AND THE RETORTED RESIDUE WILL BE DISPOSED OF IN THE CANYON. WATER WILL BE RECYCLED AND TOTALLY CONSUED, THUS NO CONTAMINATION OF STREAMS OR GROUND WATER CAN OCCUR. RAW SHALE OIL MUST BE UPGRADED TO SYNTHETIC CRUDE OIL BEFORE SHIPPING AND SUCH FACILITIES WILL BE INSTALLED IN THE VALLEY ABOUT TEN MILES FROM THE RETORTING PLANT.

LOOKING AHEAD, WE BELIEVE THAT BY THE END OF THIS CENTURY A SIGNIFICANT OIL SHALE INDUSTRY WILL HAVE BEEN ESTABLISHED WHICH WILL BE MAKING A CONTRIBUTION TO THE WORLD ENERGY NEEDS AND EVENTUALLY IN THE ORDER OF SEVERAL MILLION BARRELS PER DAY.

TODAY I AM PLEASED TO ANNOUNCE THAT THE UNION OIL COMPANY HAS STARTED TO PROCEED WITH THE INSTALLATION OF A FIFTY THOUSAND BARREL PER DAY SHALE OIL PLANT IN COLORADO IN THE BELIEF THAT ADEQUATE FINANCIAL ASSISTANCE CAN BE NEGOTIATED WITH THE FEDERAL GOVERNMENT.

OUR CONSTRUCTION SCHEDULE CALLS FOR THE BUILDING OF A TWELVE THOUSAND FIVE HUNDRED TON PER DAY MINE AND RETORT AND A TEN THOUSAND BARREL PER DAY RAW SHALE OIL UPGRADING FACILITY WITH A COMPLETION DATE OF 1983.

FOLLOWING ALONG WILL BE FOUR MORE MINES AND RETORTS AND TWO TWENTY THOUSAND BARREL PER DAY UPGRADING FACILITIES. FULL FIFTY THOUSAND BARREL PER DAY OPERATION IS EXPECTED BY 1988.

THE SYNTHETIC SHALE OIL PRODUCTION WILL BE OF HIGHER QUALITY THAN ANY KNOWN CONVENTIONAL CRUDE OIL. IT WILL BE ESSENTIALLY FREE OF SULFUR AND NITROGEN AND RESIDUAL. A TYPICAL MODERN REFINERY COULD CONVERT THE SYNTHETIC CRUDE INTO ONE HUNDRED PERCENT TRANSPORTATION PRODUCTS.

IT HAS BEEN A PLEASURE TO PARTICIPATE IN THIS MEETING TODAY AND I WOULD BE PLEASED TO ANSWER ANY QUESTIONS.

AIR FORCE ENERGY MANAGEMENT

MAJ GEN LAWRENCE D. GARRISON
DIRECTOR OF MAINTENANCE AND SUPPLY
HQ USAF

AIR FORCE SPECIAL
ASSISTANT FOR ENERGY

COVER SLIDE ON

GOOD AFTERNOON LADIES & GENTLEMEN:

ITS A PLEASURE TO BE IN SAN ANTONIO, AND I'M PARTICULARLY PLEASED TO HAVE AN OPPPORTUNITY TO SPEAK AT THE INDUSTRY -MILITARY ENERGY SYMPOSIUM.

THIS AFTERNOON I WILL ADDRESS AIR FORCE ENERGY MANAGEMENT —

- HOW WELL WE HAVE DONE IN OUR ENERGY CONSERVATION PROGRAMS;
- SOME THINGS THAT HAVE PROVEN TO BE SUCCESSFUL FOR US AND
- SOME NEW INITIATIVES THAT WE HOPE WILL BE EVEN MORE SUCCESSFUL IN THE FUTURE.

COVER SLIDE OFF

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ENERGY MANAGEMENT

- ORGANIZATION
- AIR FORCE SHARE OF DOD ENERGY CONSUMPTION
- COST AND CONSUMPTION TRENDS
- AIRCRAFT OPERATIONS
- VEHICLE OPERATIONS
- FACILITY ENERGY
- SUMMARY

SLIDE #1 ON

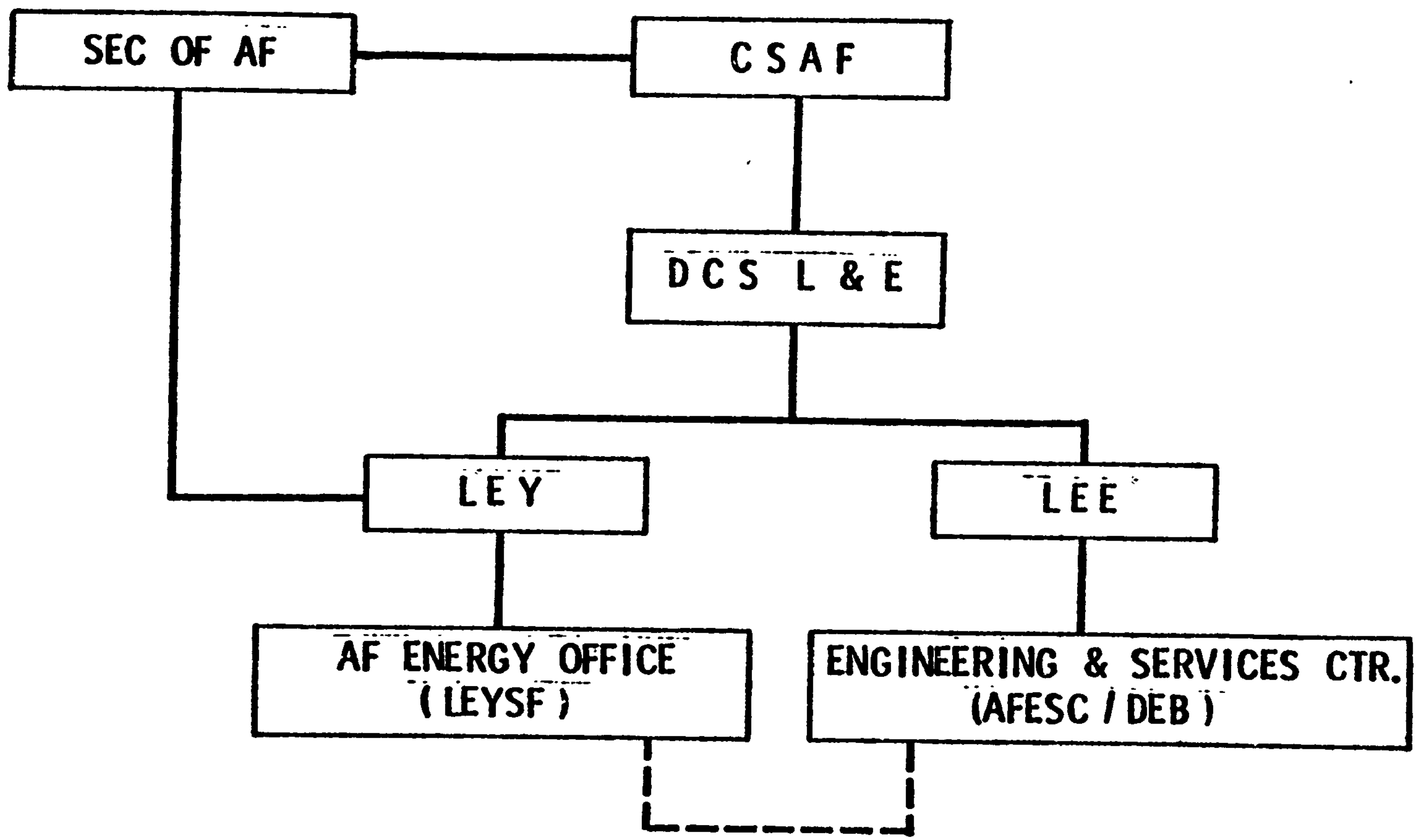
THIS IS A LIST OF THE MAJOR TOPICS I WILL ADDRESS

SLIDE #1 OFF

USAF L&E DCS/Logistics & Engineering

ENERGY MANAGEMENT

ENERGY MANAGEMENT ORGANIZATION



SLIDE #2 ON

I THINK IT'S APPROPRIATE THAT I BEGIN BY LETTING YOU KNOW WHERE I FIT IN THE OVERALL ENERGY MANAGEMENT STRUCTURE.

THIS SLIDE IS AN OVER-SIMPLIFICATION OF THE ENERGY ORGANIZATION, BUT I THINK IT WILL SUIT MY PURPOSE. I CURRENTLY SERVE AS THE DIRECTOR OF MAINTENANCE AND SUPPLY, FOR THE DEPUTY CHIEF OF STAFF LOGISTICS AND ENGINEERING. I ALSO ACT AS THE AIR FORCE SPECIAL ASSISTANT FOR ENERGY FOR THE UNDER SECRETARY OF THE AIR FORCE. THE AIR FORCE ENERGY OFFICE IS MY PRIME ENERGY SUPPORT ORGANIZATION AND IS THE FOCAL POINT FOR ALL ENERGY MATTERS BETWEEN THE AIR FORCE AND THE DEPARTMENT OF DEFENSE.

SLIDE #2 OFF

USAF L&E 42 DCS/Logistics & Engineering

AIR FORCE SHARE OF DOD ENERGY CONSUMPTION

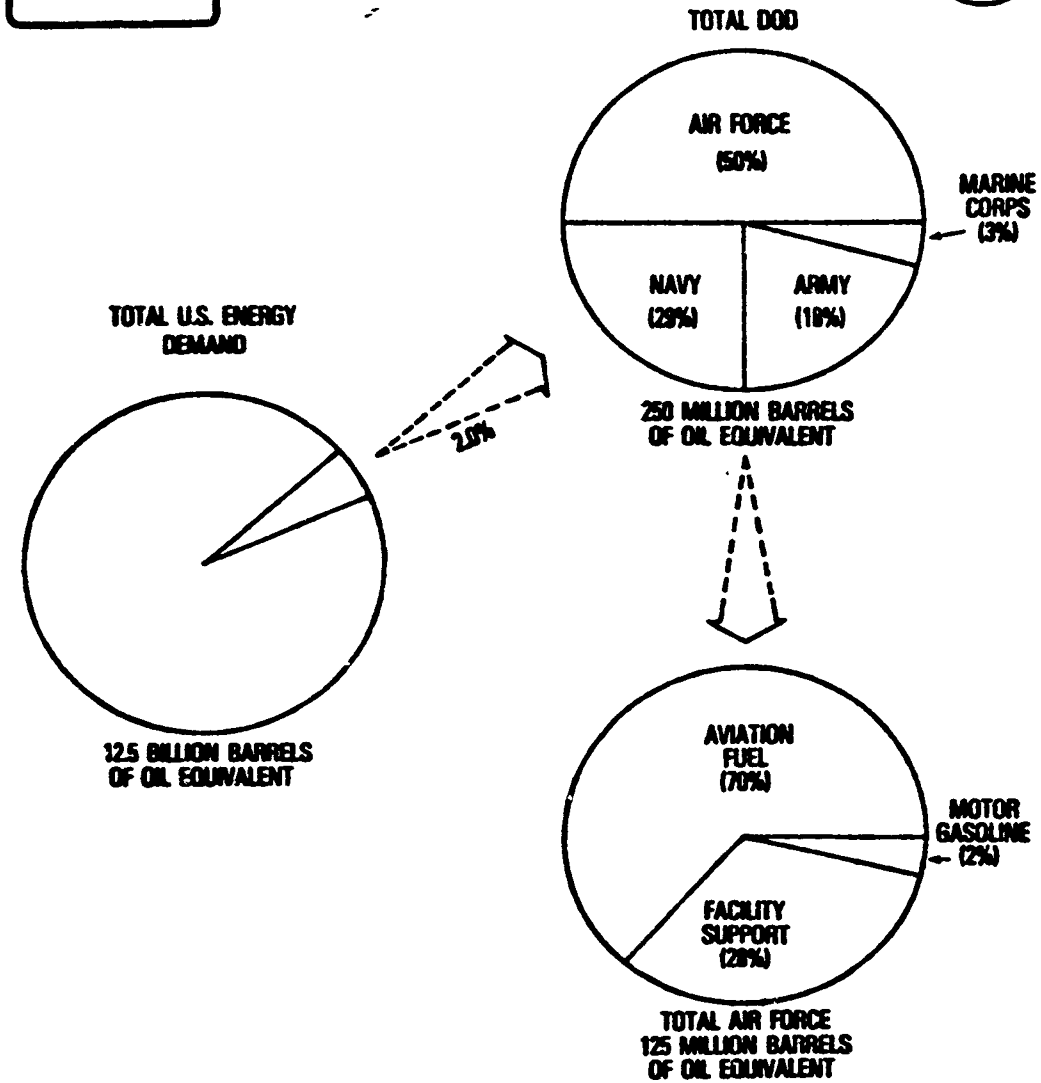
SLIDE # 3 ON

WE WILL NOW LOOK AT THE AIR FORCE's PART OF THE DEPARTMENT CF DEFENSE CONSUMPTION

SLIDE # 3 OFF

ENERGY MANAGEMENT

ENERGY DEMANDS



SLIDE #4 ON

ALTHOUGH DOD IS THE LARGEST ENERGY CONSUMER IN THE FEDERAL GOVERNMENT, THIS REPRESENTS ONLY 2 PERCENT OF THE TOTAL U.S. ENERGY DEMAND. WITHIN DOD, THE AIR FORCE IS THE LARGEST CONSUMER USING 50 PERCENT OF DOD's ENERGY REQUIREMENT. THE AIR FORCE CONSUMPTION IS DRIVEN BY AVIATION FUEL DEMAND WHICH ACCOUNTS FOR OVER 70 PERCENT OF AIR FORCE ENERGY.

SLIDE #4 OFF

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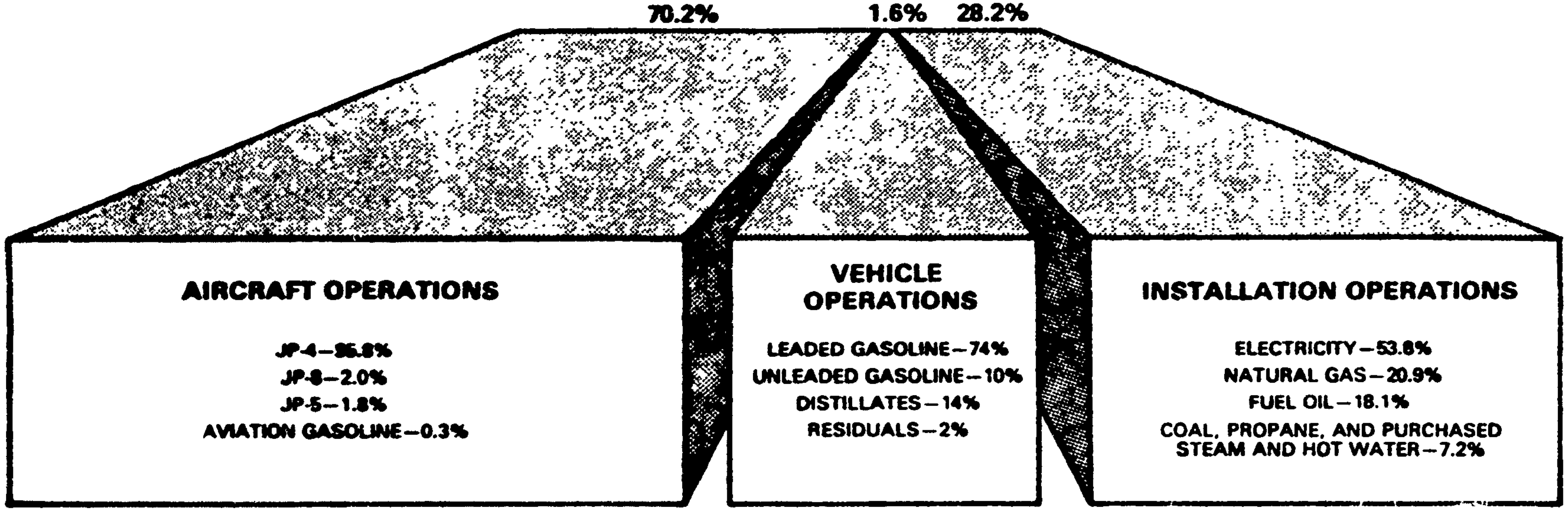
ENERGY MANAGEMENT

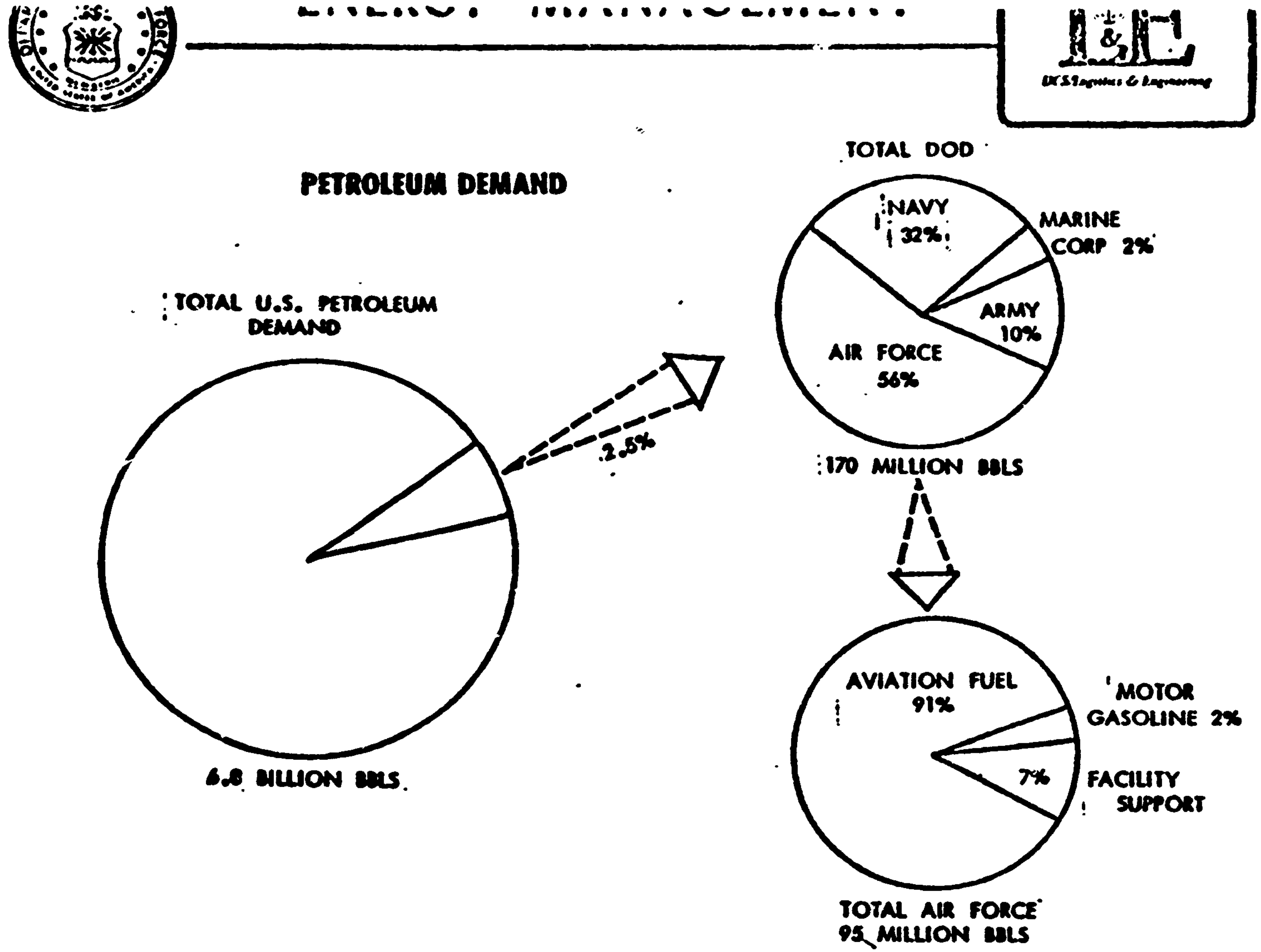
**AIR FORCE FY 1979 ENERGY USAGE
BY ACTIVITY AND FUEL TYPE**



SLIDE #5 ON

A FURTHER BREAKDOWN OF THE AIR FORCE ENERGY USAGE SHOWS THE DOMINANT ENERGY SOURCE IN EACH MAJOR CATEGORY. JP-4 IN AIRCRAFT OPERATIONS REPRESENTS ALMOST 96 PERCENT OF THE JET FUEL; LEADED GASOLINE IN VEHICLES REPRESENT 74 PERCENT; AND ELECTRICITY IS THE PRIMARY ENERGY SOURCE IN INSTALLATION OPERATION, REPRESENTING 53.8%.

SLIDE #5 OFF


PETROLEUM DEMAND
TOTAL U.S. PETROLEUM DEMAND
6.8 BILLION BBLS
2.5%
TOTAL DOD
NAVY 32%
MARINE CORP 2%
ARMY 10%
AIR FORCE 56%
170 MILLION BBLS
AVIATION FUEL 91%
MOTOR GASOLINE 2%
7%
FACILITY SUPPORT
TOTAL AIR FORCE 95 MILLION BBLS

SLIDE #6 ON

IF WE CONSIDER ONLY PETROLEUM DEMAND, DOD'S SHARE OF THE U.S. CONSUMPTION IS 2.5 PERCENT. THE AIR FORCE IS ALSO THE LARGEST PETROLEUM CONSUMER IN DOD WITH 56 PERCENT OF THE TOTAL DEMAND. AVIATION FUEL REMAINS THE DOMINANT CONSUMPTION AREA IN THE AIR FORCE, REPRESENTING 91 PERCENT OF THE TOTAL PETROLEUM REQUIREMENT.

SLIDE #6 OFF

COST & CONSUMPTION TRENDS

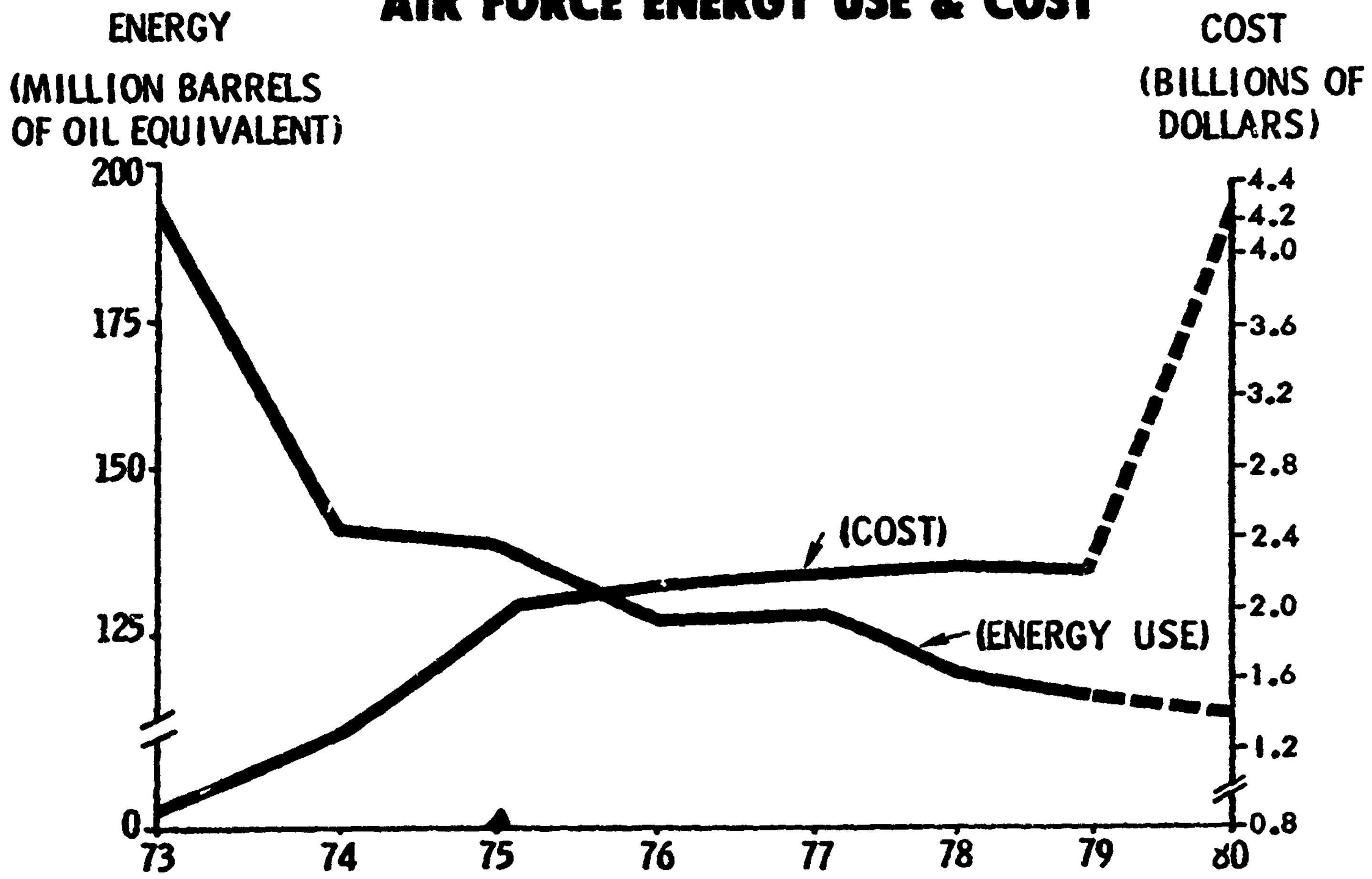
SLIDE #7 ON

NOW LETS TAKE A LOOK AT THE ENERGY COST AND COMSUMPTION PATTERNS IN THE AIR FORCE

SLIDE #7 OFF

ENERGY MANAGEMENT

AIR FORCE ENERGY USE & COST



FY 73 - FY 75 CONSUMPTION REDUCED 29%

FY 75 - FY 79 CONSUMPTION REDUCED 8%

SLIDE #8 ON

IN 1973 THE ARAB OIL EMBARGO HAD A REAL IMPACT ON BOTH THE AVAILABILITY OF OIL SUPPLIES AND THE RAPID ESCALATION OF COST. SINCE 1973, ALTHOUGH AIR FORCE ENERGY CONSUMPTION HAS BEEN DECREASED BY ALMOST 35 PERCENT, ENERGY COSTS HAVE INCREASED OVER 330 PERCENT. FOR FY 80 THE COST INCREASED DRAMATICALLY, TO OVER 4.2 BILLION DOLLARS, MORE THAN A 100 PERCENT INCREASE OVER THE FY 79 COST. EACH ONE CENT INCREASE PER GALLON OF JET FUEL COSTS THE AIR FORCE ABOUT $36 MILLION PER YEAR GIVEN OUR CURRENT FLYING HOUR PROGRAM.

FLYING HOUR PROGRAM 3.2 MIL HRS.

	FY 73	FY 79
FUEL USE:	190	125 (MBBL OF OIL EQUIV.)
COST:	$970 MIL	$4.2 BILLION

SLIDE #8 OFF

ENERGY MANAGEMENT

USAF L&E
DCS/Logistics & Engineering

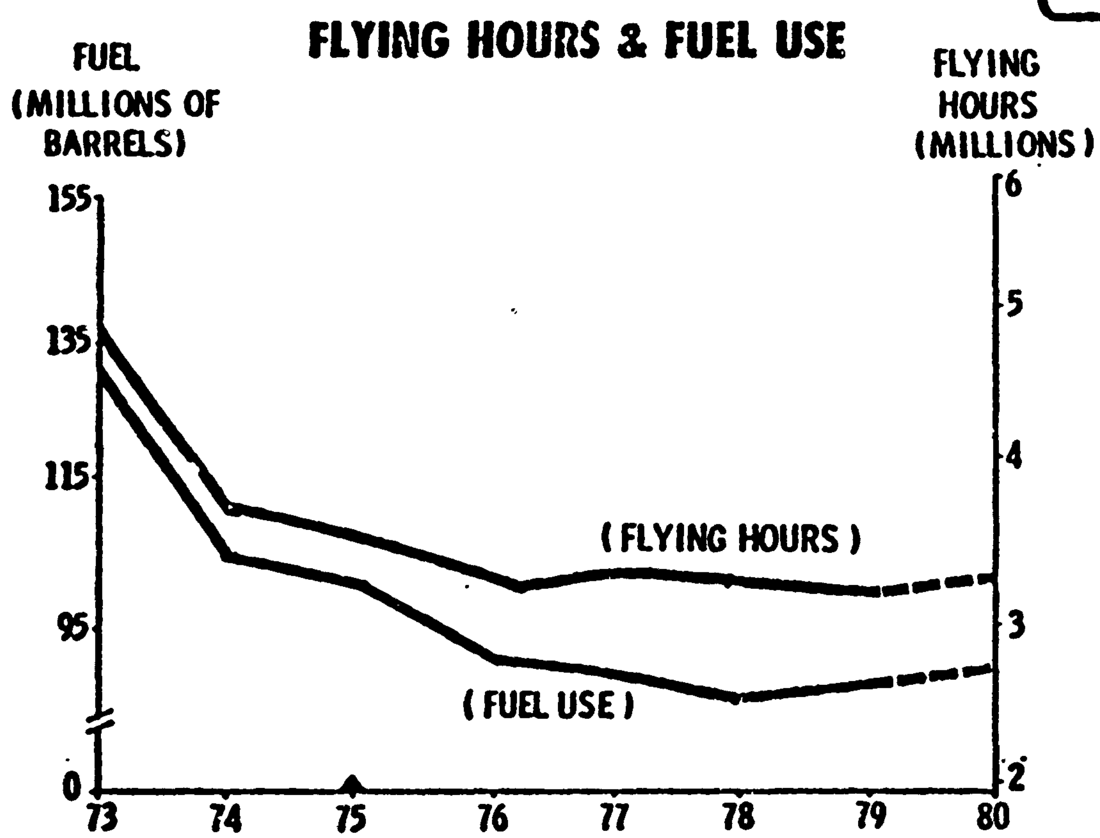
AIRCRAFT OPERATIONS

SLIDE # 9 ON

AS YOU RECALL AIRCRAFT OPERATIONS CONSUME ABOUT 91 PERCENT OF OUR PETROLEUM DEMAND. OUR OBJECTIVE IN THIS AREA IS TO CONTINUE TO REDUCE ENERGY CONSUMPTIOON WHILE INSURING THAT COMBAT READINESS IS MAINTAINED. TO DATE WE HAVE ACHIEVED THIS OBJECTIVE AND MUCH OF IT BY SUCCESSFULLY ADVOIDING FLYING HOURS.

SLIDE # 9 OFF

ENERGY MANAGEMENT



FY 73 - FY 75 CONSUMPTION REDUCED 27%

FY 75 - FY 79 CONSUMPTION REDUCED 7.5%

SLIDE # 10 ON

AS NOTED BY THIS SLIDE, OUR MAJOR ACHIEVEMENTS IN CONSERVING ENERGY IN AIRCRAFT OPERATIONS IS PRIMARILY DRIVEN BY OUR FLYING HOUR PROGRAM. FROM 1973 TO 1975 BOTH FLYING HOURS AND FUEL CONSUMPTION WERE REDUCED BY 35 ABOUT PERCENT. THIS FLYING HOUR ADVOIDANCE HAS BEEN ACHIEVED BY SEVERAL MEANS.

SLIDE # 10 OFF

ENERGY MANAGEMENT

- FLYING HOUR AVOIDANCE ACHIEVED BY
  - MANAGEMENT PROGRAM
  - NEWER AIRCRAFT
  - USE OF SIMULATORS

SLIDE # 11 ON

THREE OF THE WAYS WE HAVE AVOIDED FLYING HOURS IS SHOWN HERE:

-MANAGEMENT OF OUR FLYING PROGRAM -- DEVELOPMENT OF EVENT ORIENTED FLIGHTS OR PRE-FLIGHT PLANNING SUCH AS COMPUTERILZED FLIGHT PLANS, HAVE CONTRIBUTED SIGNIFICANTLY TO FLYING HOUR AVOIDANCE. CURRENT EVALUATION OF AN ON-BOARD COMPUTERIZED FLIGHT ADVISORY SYSTEM, WHICH I WILL DISCUSS LATER, OFFERS EVEN MORE POTENTIAL FOR OPTIMUM ENERGY EFFICIENCY IN AIRCRAFT OPERATIONS.

-NEWER AIRCRAFT COMING INTO THE AIR FORCE INVENTORY HAVE ALSO CONTRIBUTED TO OUR SUCCESS IN FLYING HOUR AVOIDANCE. HAVING MORE EFFICIENT ENGINES AND BETTER AERODYNAMIC DESIGN THEY GENERALLY ACHIEVE BETTER FUEL ECONOMY THAN THEIR PREDECESSORS. A NEW TRAINING AIRCRAFT IN THE PRIMARY PHASE OF FLIGHT TRAINING WILL SAVE ABOUT 25 MILLION GALLONS OF FUEL ANNUALLY. A SAC INITIATIVE TO PROCURE A COMPANION TRAINER AIRCRAFT (CTA) WHICH CAN BE FLOWN BY BOMBER CREWS IN PLACE OF SOME B-52 HOURS WILL SAVE ALMOST 50 MILLION GALLONS OF FUEL ANNUALLY.

-IN ADDITION, SIMULATORS HAVE PLAYED A MAJOR ROLE IN OUR FLYING HOUR AVOIDANCE.

SLIDE # 11 OFF

PICTURE OF SIMULATOR

SLIDE # 12 ON

FOR EXAMPLE, SIMULATORS, SUCH AS THE ONE SHOWN HERE, WERE USED MORE THAN 225,000 HOURS IN FY 79 IN SUPPORT OF PILOT TRAINING PROGRAMS. THIS EQUATES TO A SAVINGS OF APPROXIMATELY 6 MILLION BARRELS OR A COST AVOIDANCE OF MORE THAN $290 MILLION. FUTURE SIMULATOR ACQUISITIONS ARE ESTIMATED TO COST SOME $1.7 BILLION BY FY 85.

SLIDE # 12 OFF

THE SAVINGS IN AIRCRAFT OPERATIONS THAT I HAVE DISCUSSED ARE EXPECTED TO IMPROVE OVER THE NEXT FEW YEARS. R&D PROGRAMS LOOKING AT USING LIGTHER, STRONGER MATERIALS IN AIRCRAFT DESIGN AND SMOOTHNESS COATINGS FOR NEW AND OLD ENGINES WILL POSSIBLY PROVIDE FURTHER ENERGY REDUCTIONS OF PERHAPS 2-3 PERCENT. IN ADDITION, AIRCRAFT MODIFICATIONS BEING CONSIDERED WILL HAVE AN EVEN GREATER IMPACT.

PICTURE OF C-141

SLIDE #13 ON

FOR EXAMPLE, AS PREVIOUSLY MENTIONED, ON OUR LARGER AIRCRAFT IN THE AIR FORCE, SUCH AS THE C-5, B-52, KC-135 AND THE C-141 AS SHOWN HERE, WE ARE EVALUATING THE INSTALLATION OF A FUELS SAVINGS ADVISORY SYSTEM. THE ADVISORY SYSTEM IS A COMPUTERIZED ON-BOARD INFORMATION SYSTEM THAT PROVIDES THE PILOT REAL TIME DATA SUCH AS OPTIMUM TRAJECTORY PROFILES FOR TAKEOFF, CLIMB, CRUISE, AND DESCENT FOR MAXIMUM FUEL EFFICIENCY. WE CONDUCTED TESTS ON KC-135'S B-52'S AND C-141'S AND RESULTS INDICATE THAT A FUEL SAVINGS OF 4 PERCENT IS NOMINAL. THIS WOULD EQUATE TO ABOUT 60 MILLION GALLONS PER YEAR SAVINGS IF INSTALLED IN ALL AIRCRAFT CONSIDERED. (1550 ACFT)

COST: $200 MIL

NOTE: HAND HELD COMPUTERS ARE BEING CONSIDERED AS ALTERNATIVE.

SLIDE #13 OFF

PICTURE OF KC-135

SLIDE #14 ON

ON THE KC-135 THE RE-ENGINING PROGRAM WOULD REPLACE THE CURRENT PROPULSION SYSTEM WITH THE LATEST GENERATION ENGINE. THE NEW ENGINES BEING CONSIDERED WILL HAVE INCREASED THRUST, LESS NOISE POLLUTION, AND LOWER FUEL CONSUMPTION. FUEL SAVINGS ARE ESTIMATED AT ABOUT 125 MILLION GALLONS PER YEAR GIVEN ALL THE PRIMARY KC-135 AIRCRAFT ASSIGNED (615) ARE RE-ENGINED. IF FUNDED, ABOUT 131 AIRCRAFT WOULD BE CONSIDERED AS THE FIRST PHASE OF CONVERSION WITH A 14-17 YEAR PAYBACK. THE MOD WOULD EXTEND THE LIFE OF THE KC-135 WELL INTO THE 21 CENTURY.

NOTE: Not supported by Sec Def in budget, but $60 million appropriated by Congress for follow-on production. A small start of 9 aircraft is being considered by ASD (MRA&L) as a proposal to Dr. Brown.

$6 BIL COST

$10 MIL/ACFT

PAYBACK - 14 -17½ YRS

SLIDE #14 OFF

PICTURE OF KC-135 (with winglets)

SLIDE #15 ON

ALSO CONSIDERED FOR THE KC-135 IS THE INSTALLATION OF WINGLETS AS SHOWN ON THE AIRCRAFT IN THIS PHOTO. THE WINGLETS WOULD IMPROVE THE AERODYNAMIC EFFICIENCY OF THE AIRCRAFT AND PRODUCE AN ESTIMATED FUEL SAVINGS OF 68,000 GALLONS PER AIRCRAFT PER YEAR. THIS REPRESENTS A SAVINGS OF MORE THAN 35 MILLION GALLONS OF FUEL PER YEAR IF THE MOD IS INSTALLED ON ALL THE PRIMARY KC-135 AIRCRAFT ASSIGNED (615)

NOTE: NASA has just completed testing and a program review will be conducted by AFSC sometime after 1 Nov 80.

$150 MIL COST

7 - 10 YEAR PAYBACK

SLIDE #15 OFF

ENERGY MANAGEMENT

USAF L&E DCS/Logistics & Engineering

VEHICLE OPERATIONS

SLIDE #16 ON

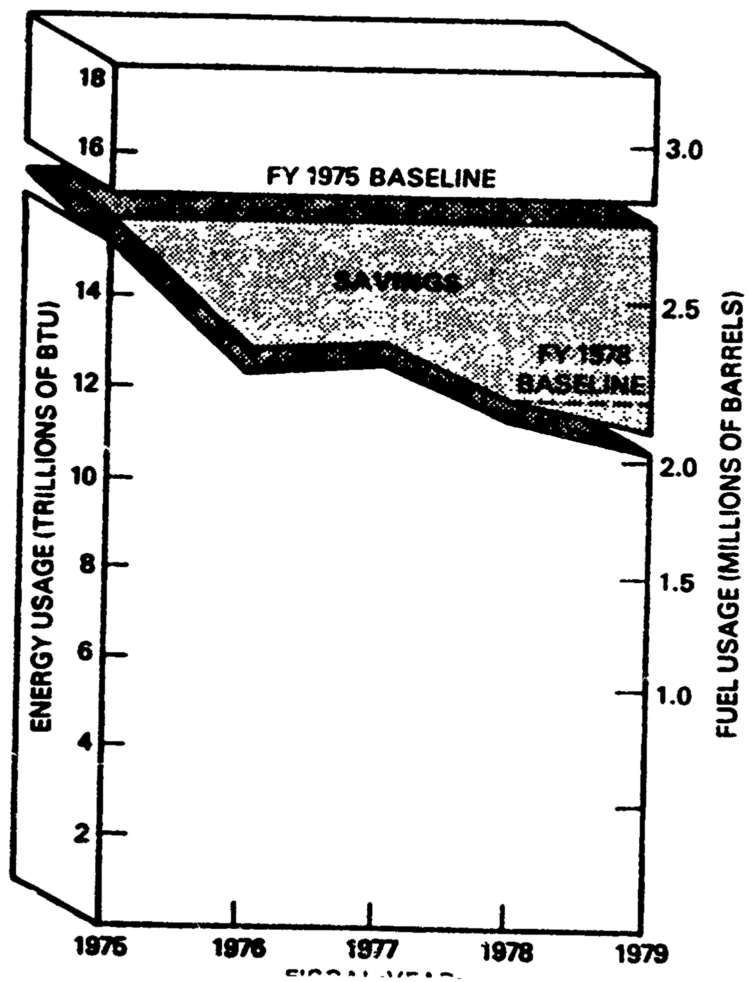
FUEL CONSERVATION MEASURES ARE ALSO APPLIED TO OUR VEHICLE OPERATIONS. AS YOU RECALL, VEHICLES REPRESENT LESS THAN 2 PERCENT OF THE PETROLEUM CONSUMPTION.

SLIDE #16 OFF

ENERGY MANAGEMENT

VEHICLE OPERATIONS

FUEL USAGE



SLIDE #17 ON

AUTOMOTIVE FUEL CONSUMPTION IN THE AIR FORCE HAS DRAMATICALLY DECREASED SINCE 1973 - AN OVERALL 42 PERCENT REDUCTION. FROM 1975 TO 1979 THE REDUCTION WAS APPROXIMATELY 18 PERCENT. OVERALL THE AIR FORCE HAS REDUCED ITS ENERGY USAGE FOR VEHICLE OPERATIONS FROM ABOUT 2.8 MILLION BARRELS IN FY 75 TO ABOUT 2 MILLION BARRELS IN FY 79.

SLIDE #17 OFF

ENERGY MANAGEMENT

VEHICLE OPERATIONS INITIATIVES

- DOWNSIZING PROGRAM
- CONVERSION TO DIESEL ENGINES
- EMPHASIZING MASS TRANSIT

SLIDE #18 ON

THE REDUCTIONS IN VEHICLE CONSUMPTION WERE PRIMARILY ACHIEVED BY

LOCAL CONSERVATION ACTION - HOW, WHY WHEN VEHICLES ARE USED AND

BY OUR VEHICLE PURCHASE PROGRAM - THAT IS, PURCHASING BETTER MILEAGE EFFICIENT VEHICLES AND PURCHASING THE RIGHT VEHICLE FOR THE RIGHT JOB.

IN THIS RESPECT, THE AIR FORCE IS WORKING THREE VEHICLE OPERATION INITIATIVES.

- DOWNSIZING PROGRAM OR THE PURCHASE OF COMPACT VEHICLE
- CONVERSION TO DIESEL ENGINE AND
- EMPHASIZING MASS TRANSIT.

SLIDE #18 OFF

PICTURE OF COMPACT PICK-UP WITH MAINTENANCE BODY

SLIDE #19 ON

AN EXAMPLE OF THE DOWNSIZING PROGRAM IS SHOWN HERE. THE COMPACT PICK-UP WITH MAINTENANCE BODY IS ONE OF THE WAYS WE HAVE BEEN ABLE TO SUCCESSFULLY ADAPT TO THE SMALLER VEHICLES. THE AIR FORCE IS PROCURING AS MANY COMPACT VEHICLES, PICK-UPS, SEDANS AND STATION WAGONS AS THE CURRENT BUDGET WILL ALLOW.

WE CURRENTLY HAVE:

1595 COMPACT SEDANS (50%)

1468 COMPACT STATION WAGONS (60%)

317 COMPACT PICK-UPS ON-BOARD (10%)

SLIDE #19 OFF

PICTURE OF TRUCK TRACTOR

SLIDE #20 ON

THIS PHOTO OF A TRUCK TRACTOR IS A GOOD EXAMPLE OF THE DIESEL CONVERSION PROGRAM. ALL FUTURE PROCUREMENTS OF TRUCK TRACTORS, REFUELING UNITS, FORK LIFTS ETC. WILL BE DIESEL WHEN POSSIBLE.

SLIDE #20 OFF

PICTURE OF 15 PASSENGER VAN

SLIDE #21 ON

AS AN EXAMPLE ON THE EMPHASIS ON MASS TRANSIT, WE ARE CONVERTING MORE AND MORE OF OUR 28 PASSENGER BUSSES TO THIS 15 PASSENGER CONFIGURATION. THIS EXCHANGE ENHANCES USE AND CONTRIBUTES TO ENERGY SAVINGS.

SLIDE #21 OFF

FACILITY ENERGY

SLIDE #22 ON

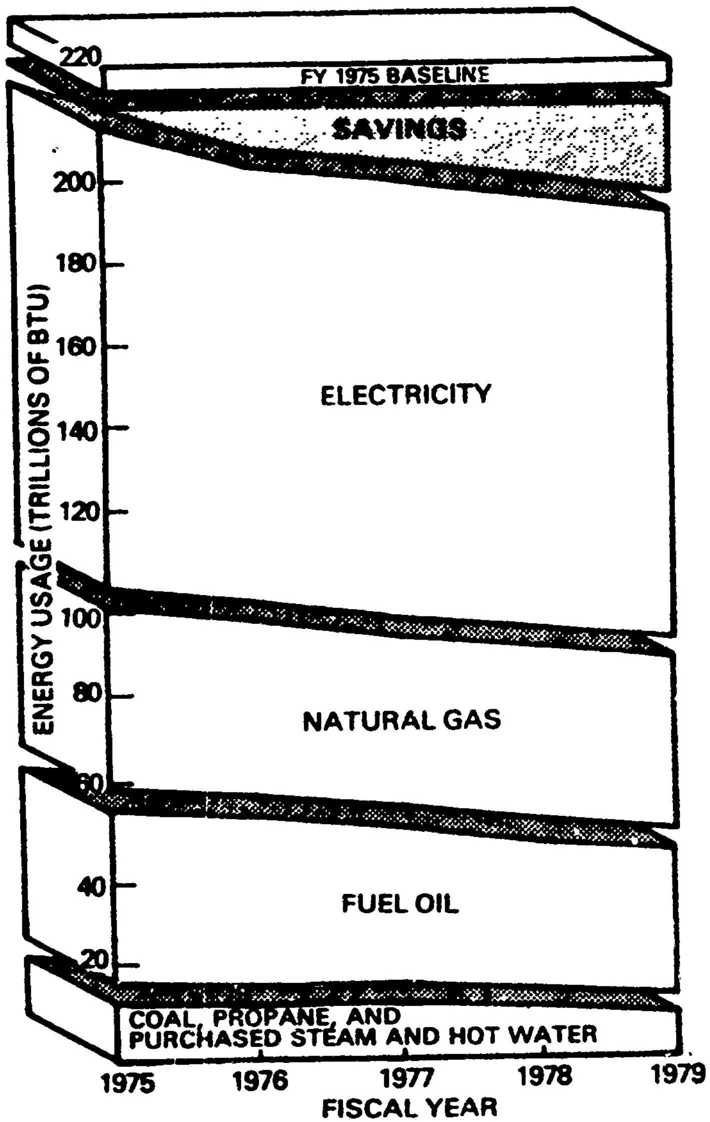
THE FACILITY ENERGY CONSUMPTION IN THE AIR FORCE IS 28 PERCENT OF THE TOTAL ENERGY DEMAND OR 7 PERCENT OF THE PETROLEUM CONSUMED.

SLIDE #22 OFF

ENERGY MANAGEMENT

DCS/Logistics & Engineering

INSTALLATION OPERATIONS ENERGY USAGE BY FUEL TYPE



SLIDE #23 ON

AS WITH AIRCRAFT AND VEHICLE OPERATIONS, FACILITY ENERGY CONSUMPTION HAS BEEN CONSIDERABLY REDUCED SINCE 1973. TOTAL REDUCTION IN FACILITY ENERGY USE FROM 1973 TO 1975 WAS APPROXIMATELY 19 PERCENT. IN FY 79 THE AIR FORCE REDUCED ENERGY USAGE AN ADDITIONAL 10.9 PERCENT FROM FY 75 CONSUMPTION.

SLIDE #23 OFF

ENERGY MANAGEMENT

DCS/Logistics & Engineering

FACILITY ENERGY PROGRAM

1985 OBJECTIVES

- 20% REDUCTION-EXISTING FACILITIES
  - 12% BY ENERGY CONSERVATION INVESTMENT PROGRAM
  - 8% BY LOCAL CONSERVATION ACTIONS (O&M FUNDS)
- 45% REDUCTION-NEW FACILITIES
- 1% FROM SOLAR/GEOTHERMAL
- 10% FROM COAL, REFUSE DERIVED FUEL OR BIOMASS

SLIDE #24 ON

THE AIR FORCE FACILITY ENERGY PROGRAM IS DRIVEN BY THE OBJECTIVES AS SHOWN HERE. THE FIRST TWO ARE REQUIRED BY A PRESIDENTIAL EXECUTIVE ORDER AND THE LATTER TWO ARE DOD REQUIREMENTS.

THE 20 PERCENT OBJECTIVE IS TO BE PRIMARILY ACHIEVED BY CAPITAL INVESTMENT IN RETROFIT ACTION SUCH AS NEW MORE EFFICIENT HEATING SYSTEM ETC, (ENERGY CONSERVATION INVESTMENT PROGRAM) AND THROUGH LOCAL USE OF O&M FUNDS COUPLED WITH STRONG MANAGEMENT ACTIONS.

THE 45 PERCENT OBJECTIVE CAN BE ACHIEVED BY DESIGNING ENERGY EFFICIENT BUILDING AND USE OF NEW MATERIALS IN THESE DESIGN. THE OBJECTIVE IS CONSIDERED OBTAINABLE BY 1985.

THE 1 PERCENT OBJECTIVE IN SOLAR IS NOT EASY TO ACHIEVE. ALTHOUGH 28 SOLAR SYSTEMS ARE OPERATIONAL IN THE AIR FORCE AND 35 MORE UNDER CONSTRUCTION OR IN DESIGN, SOLAR ENERGY, IS NOT GENERALLY CONSIDERED A COST EFFECTIVE INVESTMENT. IN OUR EXPERIENCE, THE PAYBACK IS NOT WITHIN THE LIFE OF THE SYSTEM. BEFORE THE AIR FORCE WILL CONSIDER INSTALLATION OF SOLAR SYSTEMS WE MUST HAVE THE POTENTIAL OF A 25 YEAR OR LESS PAYBACK. TO ACHIEVE THE ONE PERCENT OBJECTIVE WILL REQUIRE MANY MORE PROJECTS AND WILL COST THE AIR FORCE MORE THAN $400 MILLION.

NOTE: DOE funds a good bit of the solar as demostration projects.

THE LAST MAJOR OBJECTIVE OF 10 PERCENT FROM COAL, REFUSE DERIVED FUEL OR BROMASS IS ALSO DIFFICULT TO ACHIEVE. THE OBSTACLES IN THIS CASE BEING HIGH COST AND TOUGH ENVIRONMENTAL RESTRICTIONS. CURRENTLY THE AIR FORCE GETS ABOUT 6.6 PERCENT OF ITS FACILITY ENERGY FROM COAL AND TO ACHIEVE THE ADDITIONAL 3.4 PERCENT IS ESTIMATED TO COST AS MUCH AS $230 MILLION. SEVERAL COAL CONVERSION PROJECTS ARE PROGRAMED DURING THE NEXT FEW YEARS IF FUNDING BECOMES AVAILABLE. WE ALSO HAVE A REFUSE DERIVED FUEL PLANT UNDER CONSTRUCTION AT WRIGHT PATTERSON AFB.

SLIDE #24 OFF

PICTURE OF EMCS

SLIDE #25 ON

THIS IS A PICTURE OF AN ENERGY MONITORING AND CONTROL SYSTEM AT LACKLAND AFB AND IS A GOOD EXAMPLE OF THE USE OF ENERGY CONSERVATION INVESTMENT PROGRAM FUNDING. THE SYSTEM IS A COMPUTER BASED CENTRAL SURVILLANCE AND CONTROL SYSTEM WHICH MONTORS AND CONTROLS FACILITY HEATING, VENTALIZATION AND AIR CONDITIONING SYSTEMS THROUGHOUT A BASE. THERE IS CURRENTLY 23 OF THESE SYSTEMS IN OPERATION IN THE AIR FORCE. THEY ACHIEVE ENERGY REDUCTIONS AS HIGH AS 30 PERCENT ON THE FACILITIES MONITORED BY THE SYSTEM.

SLIDE #25 OFF

PICTURE OF RANDOLPH AFB BASE EXCHANGE

SLIDE #26 ON

A EXAMPLE OF THE USE OF SOLAR ENERGY, IS THIS PROJECT AT RANDOLPH AFB TX. THE MAIN EXCHANGE IS BOTH HEATED AND COOLED BY THE SOLAR PANELS VISABLE ON THE ROOF OF THE BLDG. THIS SYSTEM COST $476,000 AND WAS A DEPARTMENT OF ENERGY DEMOSTRATION PROJECT. NASA IS CURRENTLY EVALUATING THE PROJECT TO DETERMINE THE EFFICIENCY OF THE SYSTEM AND PROJECTED PAYBACK. WE'RE WATCHING THE OUTCOME CLOSELY.

GEOTHERMAL ENERGY IS ALSO CONSIDERED UNDER THE SOLAR UMBRELLA. OUR PRIMARY INTEREST IN THIS AREA IS CENTERED AT WILLIAMS AFB WHICH OFFERS THE POTENTIAL OF A GOOD GEOTHERMAL SOURCE FOR USE AT THE BASE. STUDIES ARE UNDERWAY AT WILLIAMS TO DETERMINE MEANS OF TAPPING THE GEOTHERMAL ENERGY.

SLIDE #26 OFF

PHOTO OF PHOTOVOLTAIC ARRAY AT MT LAGUNA AFS CALIF.

SLIDE #27 ON

AN EXAMPLE OF OUR SOLAR RESEARCH IS THIS PHOTOVOLTAIC PROJECT AT MT. LAGUANA. THIS FIELD ARRAY PROVIDES ABOUT 10 PERCENT OF THE POWER REQUIREMENTS OF THE SITE DURING DAYLIGHT HOURS. THIS PROJECT WAS ALSO A JOINT DOD/DOE DEMONSTRATION INITIATIVE.

SLIDE #27 OFF

PHOTO OF WIND GENERATOR - FRANCIS E. WARREN AFB

SLIDE #28 ON

IN WIND ENERGY - SMALL SCALE GENERATOR SUCH AS THE ONE SHOWN HERE AT FRANCIS E. WARREN AFB, OFFERS THE MOST POTENTIAL FOR THE AIR FORCE. WIND GENERATORS IN THE 5-15 KW RANGE CAN BE VERY USEFUL FOR PROVIDING POWER AT MANY OF OUR REMOTE OR ISOLATED LOCATION AROUND THE WORLD.

SLIDE #28 OFF

ENERGY MANAGEMENT

SUMMARY

- SIGNIFICANT REDUCTIONS IN ENERGY CONSUMPTION SINCE 1973 – 35%
- ADDITIONAL SAVINGS EXPECTED - REQUIRES LARGE CAPITAL INVESTMENT
- R & D REQUIREMENT EXTREMELY CHALLENGING
- MAY HAVE TO RESTRUCTURE PRIORITY OF CAPITAL INVESTMENT

SLIDE #29 ON

IN SUMMARY, THE AIR FORCE ENERGY PROGRAM HAS BEEN VERY SUCCESSFUL.

- SIGNIFICANT REDUCTION IN ENERGY CONSUMPTION HAVE BEEN ACHIEVED AND THIS TREND IS EXPECTED TO CONTINUE

- WE THINK, HOWEVER, THAT HEAVY CAPITAL INVESTIMENT WILL BE REQUIRED TO MAINTAIN A LONG -RANGE CONSERVATION PROGRAM.

- WE ALSO THINK THAT R&D MUST PLAY A SIGNIFICANT ROLE IF WE ARE GOING TO ACHIEVE THE BREAK THROUGHS IN ENERGY THAT WE NEED ,

- AND FINALLY, I THINK WE MAY HAVE TO LOOK HARD AT OUR PRIORTIES CONCERNING THE USE OF ENERGY. WE MUST BE PREPARED TO PLACE ENERGY CONSIDERATION IN THE SAME CATEGORY AS SAFETY AND MISSION CAPABILITIES. WE CAN NO LONGER AFFORD TO INGORE THE INEVITABLE. ENERGY MANAGEMENT AND CONSERVATION PRACTICES MUST BECOME A SIGNIFICANT PART OF OUR DAILY DECISION MAKING CRITERIA.

SLIDE #29 OFF

BRIGADIER GENERAL BRIEN D. WARD
DIRECTOR OF LABORATORIES
AIR FORCE SYSTEMS COMMAND
MILITARY/INDUSTRY ENERGY SYMPOSIUM
EL TROPICANA MOTEL
SAN ANTONIO, TEXAS
21-23 OCTOBER 1980

WELCOME TO THE AFTERNOON SESSION OF THIS MILITARY/INDUSTRY ENERGY SYMPOSIUM.

I TRUST YOUR LUNCH WAS ENOUGH TO KEEP YOUR BLOOD SUGAR UP -- AND TO WHET YOUR APPETITE FOR THIS AFTERNOON'S PRESENTATIONS.

I'M DALE WARD FROM THE AIR FORCE SYSTEMS COMMAND, THE MODERATOR FOR THIS SESSION. AT SYSTEMS COMMAND, I WEAR TWO HATS -- ONE AS THE A-F-S-C DEPUTY CHIEF OF STAFF FOR SCIENCE AND TECHNOLOGY, AND THE OTHER AS DIRECTOR OF LABORATORIES.

HERE, TODAY, I ALSO WEAR TWO HATS -- ONE AS THE SESSION MODERATOR, AND ANOTHER AS THE FIPST SPEAKER THIS AFTERNOON.

BEFORE WE GET DOWN TO BUSINESS, THERE ARE A FEW ADMINISTRATIVE DETAILS:

-- ANNOUNCEMENTS (IF ANY)

-- BREAKS SCHEDULED

-- GROUND RULES (IF ANY)

THERE ARE SIX PRESENTATIONS ON OUR PROGRAM THIS AFTERNOON.

I'LL SPEAK TO AIR FORCE WEAPON SYSTEM RELATED R&D.

MR. JOHN G. BORGER, VICE PRESIDENT OF PAN AMERICAN AIRWAYS, WILL SPEAK ON THE COMMERCIAL AVIATION OUTLOOK, FOLLOWED BY MR. FRANK W. McABEE, PRESIDENT OF GOVERNMENT PRODUCTS DIVISION OF THE PRATT AND WHITNEY AIRCRAFT CORPORATION SPEAKING ON FUTURE AVIATION ENGINE DESIGN.

GENERAL LAWRENCE R. SEAMON, COMMANDER OF THE DEFENSE FUEL SUPPLY CENTER, ON DOD FUEL REQUIREMENTS AND SUPPORT.

MR. HARRY H. JONES, DEPARTMENT OF ENERGY, DEPUTY ASSISTANT SECRETARY FOR STRATEGIC PETROLEUM RESERVE, WILL TALK ON THAT SUBJECT, THE STRATEGIC PETROLEUM RESERVES, AND THE SESSION WILL CONCLUDE WITH MR. GERHARDT NEWMAN OF GENERAL ELECTRIC WHO WILL SPEAK ON PROPULSION TECHNOLOGY.

THAT'S A FULL SCHEDULE - SO WE'D BEST GET TO IT. I'LL DON MY OTHER HAT NOW, AND SPEAK TO YOU ABOUT AIR FORCE ENERGY-RELATED RESEARCH AND DEVELOPMENT.

THE AIR FORCE ENERGY R&D PROGRAMS ARE LIMITED, IN A SENSE, BECAUSE WE ARE A MISSION AGENCY, AND THUS MAY ONLY ADDRESS THOSE ASPECTS WHICH ARE MISSION RELATED. WITHIN THOSE LIMITS, HOWEVER, OUR INTERESTS ARE BOTH BROAD AND DEEP.

WE HAVE ACTIVE, ONGOING, GROWING PROGRAMS IN VEHICLES, SIMULATORS, PROPULSION, FUELS, MOBILE POWER EQUIPMENT, AND FACILITY HEAT AND POWER.

MANY OF THESE AREAS ARE OF INTEREST TO OTHER AGENCIES: THE OTHER SERVICES, NASA AND OF COURSE THE DOE. CONSEQUENTLY, OUR PROGRAMS ARE INTERRELATED, COORDINATED, AND IN MANY INSTANCES COOPERATIVE.

THE AIR FORCE INTEREST IN ENERGY SAVINGS IS CERTAINLY NOT NEW - IN FACT, IT IS FAIR TO SAY THAT WE'VE BEEN IN THIS BUSINESS FROM THE VERY BEGINNING -- BECAUSE YOU JUST CAN'T BUILD ANY SORT OF AEROSPACE MACHINE WITHOUT BEING VITALLY CONCERNED WITH SIZE, WEIGHT, POWER, EFFICIENCY, EFFECTIVENESS AND COST.

FROM A WEAPONS SYSTEM POINT OF VIEW, THOSE ARE THE REAL DRIVERS - AND SO ARE THEY FROM AN ENERGY POINT OF VIEW.

WHAT IS NEW, AND WHAT IS REFLECTED IN OUR ONGOING PROGRAMS, IS THE DRAMATIC CHANGE IN THE ENERGY COSTS - WHICH DRASTICALLY ALTERS THE BALANCE IN SYSTEM TRADE ANALYSES: AND THE POTENTIAL SUPPLY PROBLEM WE FACE IN THE YEARS AHEAD.

LET ME PUT AIR FORCE INTERESTS IN CONTEXT: THE DOD IS THE LARGEST SINGLE (SINCE GENERAL SEAMON BUYS ALL OF IT) CONSUMER OF PETROLEUM IN THE UNITED STATES - AND YET THE DOD CONSUMES ONLY ABOUT 2-1/2 PERCENT OF THE NATIONAL TOTAL PETROLEUM. OF THE DOD CONSUMPTION, THE AIR FORCE USES A LITTLE MORE THAN HALF, AND NINETY-ONE PERCENT OF THAT CONSUMPTION IS AVIATION FUEL.

IF YOU LOOK AT THE BIG PICTURE, THE AIR FORCE PETROLEUM CONSUMPTION ISN'T ALL THAT MUCH: 56% OF 2-1/2% IS LESS THAN 1-1/2% OF NATIONAL CONSUMPTION - SO ONE COULD SAY THAT WE CAN'T DO MUCH TO HELP - BUT I WOULDN'T!

FROM A SLIGHTLY DIFFERENT POINT OF VIEW, THINGS LOOK LIKE THIS:

OUR AVERAGE DAILY FUEL CONSUMPTION IS ABOUT 235,000 BARRELS OF AVIATION FUEL.

THIS IS 38% LOWER THAN IT WAS IN 1973. THE REDUCTION IS DUE TO EXTENSIVE CONSERVATION EFFORTS - WHICH TRANSLATES ALMOST DIRECTLY TO FEWER - FLYING - HOURS.

OUR 1973 FUEL BILL, FOR 143 MILLION BARRELS, WAS UNDER $600 MILLION.

OUR 1979 FUEL BILL, FOR 96 MILLION BARRELS, WAS $1.6 BILLION.

WE EXPECT TO PAY $3.8 BILLION FOR FY 80, AND UP TO $5.0 BILLION IN FY 81.

A ONE CENT PER GALLON RISE IN THE PRICE OF JET FUEL COSTS THE AIR FORCE $36 MILLION PER YEAR.

IN WARTIME, OUR CONSUMPTION COULD MORE THAN TRIPLE, TO THREE QUARTERS OF A MILLION BARRELS PER DAY!

EVEN IN THESE DAYS OF BIG NUMBERS, THESE ARE BIG NUMBERS - BUT, MORE TO THE POINT, THE LARGE COSTS LEAD TO REDUCED FLYING HOURS, WHICH IMPACTS OUR ABILITY TO MAINTAIN A STRONG NATIONAL DEFENSE.

OUR RESEARCH AND DEVELOPMENT PROGRAM IS AIMED AT BOTH ENDS OF THE PROBLEM: AT REDUCING CONSUMPTION - WITHOUT LOSING CAPABILITY - AND AT MAKING SURE THAT WE WILL BE ABLE TO USE WHAT BECOMES AVAILABLE.

BUT, AS I MENTIONED A MOMENT AGO, THE AIR FORCE ISN'T IN THIS BUSINESS ALONE - AND, FRANKLY, THAT'S A MIXED BLESSING!

THE DEPARTMENT OF ENERGY HAS THE CHARTER TO MEET ALL OF THE NATION'S ENERGY NEEDS. THAT'S A HERCULEAN UNDERTAKING, AND WHAT WITH THE ORGANIZATIONAL, POLITICAL AND FINANCIAL TURBULENCE NATURAL TO THE EARLY YEARS OF SO LARGE AN UNDERTAKING, THE GROWING PAINS HAVE IN SOME INSTANCES APPEARED TO OUTSIDERS AS BEING VERY SEVERE!

CONSEQUENTLY, WE IN THE AIR FORCE HAVE HAD A DIFFICULT TIME MAKING REASONABLE PROGRESS IN SOME OF OUR ENERGY PROGRAMS.

DESPITE OUR CONCENTRATED EFFORTS SINCE MID-1977, WE STILL HAVE NOT BEEN ABLE TO SATISFACTORILY RESOLVE PROBLEMS OF ENERGY POLICY, PRIORITIES OR EVEN DELIVERY OF TEST FUELS.

WE RECOGNIZE THAT OUR NEEDS ARE ONLY A SPECIAL SUBJECT OF THE NATIONAL NEEDS, AND THAT IN THE POLITICAL ARENA OUR CONSTITUENCY IS NOT ALL THAT LARGE, BUT WE MUST, AND WE WILL, CONTINUE TO PRESS IMPROVEMENT TO THE PRESENT SITUATION.

OUR REQUIREMENTS FALL MAINLY IN THE "MIDDLE DISTILLATE" PART OF THE PETROLEUM PRODUCT SPECTRUM - THE TOTAL NATIONAL REQUIREMENT FOR MIDDLE DISTILLATES IS NOT INCONSIDERABLE -

- ABOUT 15% PERCENT OF THE NATION'S PETROLEUM, AND WE USE ABOUT 10 PERCENT OF THAT (THE 1.5 PERCENT MENTIONED EARLIER).

WHILE NATIONAL CONSUMPTION MIGHT PLACE OUR "PRODUCT" LOW IN PRIORITY, WE, AS THE PRIMARY AGENCY CONCERNED WITH NATIONAL DEFENSE, HAVE TO PLACE IT HIGH.

ONCE AGAIN, THIS BUSINESS ISN'T NEW TO US - WE HAD LABORATORY WORK ON SYNTHETIC AVIATION FUELS IN PROGRESS IN 1973, AND EVEN FLEW A T-39 "SABRELINER" FROM DAYTON, OHIO TO FORT WORTH, TEXAS ON SHALE-OIL DERIVED JET FUEL IN 1975.

LACK OF A CONSISTENT NATIONAL PROGRAM HAS HAMSTRUNG OUR PROGRESS. AND, FRANKLY, WHILE THE ENERGY SECURITY ACT OF 1980 IS A STEP IN THE RIGHT DIRECTION, WE BELIEVE THAT FINANCIAL INCENTIVES ALONE CANNOT DO THE JOB.

WHAT'S REALLY NEEDED IS A WELL THOUGHT-OUT AND CONSISTENT BODY OF POLICY, AND REGULATIONS, COVERING SUCH AREAS AS TAX STRUCTURE, ENVIRONMENTAL CONTROLS, PRICE STRUCTURE , AND BUSINESS PRACTICE. WITHOUT THESE, A COMPLEX SET OF FINANCIAL INCENTIVES IS NOT SUFFICIENT TO ENERGIZE THE LARGE INDUSTRY REQUIRED.

THAT'S A BRIEF VIEW OF WHAT THE ENVIRONMENT LOOKS LIKE TO US "DOWN IN THE TRENCHES" - LOTS OF OBSTACLES, SLOW AND UNCERTAIN PROGRESS, SOME PROMISE: - AND, CLEAR AND LOUD, THE NEED!

NOW I WOULD LIKE TO DISCUSS THE AIR FORCE LABORATORIES' ENERGY-RELATED WORK IN:

AEROMECHANICS, STRUCTURES, MATERIALS, PROPULSION, FUELS, SIMULATORS, AND TERRESTRIAL POWER.

WE HAVE PRIMARY RESPONSIBILITY FOR VEHICLES, PROPULSION AND RELATED FUELS WORK.

OTHER SPEAKERS TODAY WILL TALK ABOUT PROPULSION, SO I'LL LIMIT MY REMARKS IN THAT AREA. HOWEVER, WE ARE PURSUING ENGINE TECHNOLOGY STRONGLY. OUR ADVANCED TURBINE ENGINE GAS GENERATOR (ATEGG) AND ADVANCED PROPULSION SYSTEMS INTEGRATION (APSI) PROGRAMS, WHICH ARE JOINT WITH THE NAVY AND WHICH INVOLVE THE MAJOR ENGINE COMPANIES, ARE ENJOYING A HIGH LEVEL OF FUNDING - AND OF DOD AND CONGRESSIONAL SUPPORT - AND THEY HAVE MADE SIGNIFICANT PROGRESS IN TURBINE ENGINE TECHNOLOGY; NOTABLY IN ECONOMY AND DURABILITY AS WELL AS IN PERFORMANCE.

THESE PROGRAMS ARE STRONG, AND WE EXPECT CONTINUED SUCCESSES FROM THEM.

WE EXPECT ADDITIONAL REDUCTIONS IN SPECIFIC FUEL CONSUMPTION ON THE ORDER OF 5 TO 10 PERCENT BY 1985, AND OUR EARLY WORK IN VARIABLE CYCLE TECHNOLOGY SHOWS THAT BEING ABLE TO OPTIMIZE THE ENGINE CYCLE TO VARYING FLIGHT CONDITIONS HAS MAJOR PAYOFFS.

DOING WHAT YOU CAN TO MAKE THE ENGINE BURN LESS FUEL FOR A GIVEN AMOUNT OF PUSH IS A DIRECT ATTACK ON THE PROBLEM -- BUT SO IS DOING WHAT YOU CAN TO MAKE THE AIRFRAME MORE EFFICIENT SO THAT LESS PUSH IS REQUIRED.

WE HAVE VIGOROUS PROGRAMS IN AEROMECHANICS, STRUCTURES AND MATERIALS, AND THOSE PROGRAMS HAVE PAID OFF.

AS I MENTIONED EARLIER, LOOKING FOR GREATER AERODYNAMIC EFFICIENCY: THAT IS, MORE LIFT, LESS DRAG; GREATER STRUCTURAL EFFICIENCY; MORE STRENGTH; LESS WEIGHT; AND SYSTEM EFFICIENCY: MORE SYSTEM (AVIONICS, WEAPONS) PERFORMANCE, LESS AIRCRAFT POWER, IS NOT NEW IN THE AIRPLANE BUSINESS.

WHAT IS NEW IS THE COST IMPACT OF RELATIVELY SMALL IMPROVEMENTS: THE COST BENEFIT RATIO FOR FUEL CONSUMPTION REDUCING MODIFICATIONS AND INNOVATIONS IS WAY UP!

SINCE TRANSPORT AIRCRAFT OPERATE MOST OF THE TIME IN A CRUISE MODE, REDUCTIONS IN CRUISE DRAG CAN HAVE SIGNIFICANT PAYOFF.

WE HAVE NEARLY COMPLETED A THEORETICAL, COMPUTATIONAL AND FLIGHT TEST INVESTIGATION OF A POSSIBLE WINGLET MODIFICATION TO THE KC-135 "STRATOTANKER".

WINGLETS, INVENTED BY DR. WHITCOMB OF NASA, ARE AUXILIARY LIFTING SURFACES, MOUNTED AT THE WINGTIPS, AND CANTED, ROTATED, AND SWEPT WITH RESPECT TO THE WING AXIS. BY MODIFYING THE AIRFLOW OVER THE OUTER PART OF THE WING SPAN, THEY EFFECTIVELY REDUCE DRAG-DUE-TO-LIFT, WHICH IS A MAJOR DRAG COMPONENT FOR HIGH ALTITUDE CRUISING FLIGHT. THE STRUCTURAL LOAD AND WEIGHT PENALTIES ARE RELATIVELY MINOR.

OUR NOT-YET-COMPLETE FLIGHT TEST PROGRAM, USING A KC-135 TESTBED AIRCRAFT, HAS DEMONSTRATED A 5 TO 7 PERCENT REDUCTION IN CRUISE DRAG -- CONFIRMING THEORETICAL AND NUMERICAL PREDICTIONS.

THAT DRAG REDUCTION TRANSLATES INTO A 30 MILLION GALLONS PER YEAR FUEL SAVINGS, AT PRESENT USE RATES, FOR OUR FLEET OF 600 PLUS AIRCRAFT.

PRELIMINARY STUDIES, BASED ON A REASONABLE MODIFICATION SCHEDULE AND COST ESTIMATE, INDICATE A FOUR YEAR BREAKEVEN COST AND REALLY SIGNIFICANT OUTYEAR SAVINGS.

ANOTHER POSSIBILITY FOR IMPROVING AN EXISTING ASSET -- THE C-141 "STARFREIGHTER" -- EXISTS.

THE C-141 USED THE BEST AERODYNAMIC TECHNOLOGY AVAILABLE WHEN IT WAS DESIGNED -- BUT THAT WAS A GOOD MANY YEARS AGO, AND THERE HAVE BEEN INCREASES IN OUR UNDERSTANDING OF THE IMPACT OF LEADING EDGE SHAPE ON DRAG REDUCTION.

ANALYSIS AND SMALL-SCALE WIND TUNNEL TESTS SHOW THAT REDESIGN OF THE NONSTRUCTURAL LEADING EDGE OF THE C-141 WING COULD REDUCE DRAG BY 5 TO 8 PERCENT. A COMPLETE WING REDESIGN WOULD YIELD NEARLY TWICE AS MUCH IMPROVEMENT.

SIMILAR INCREMENTAL IMPROVEMENTS ARE LIKELY TO BE FOUND BY A CAREFUL "CLEANUP" OF OTHER PORTIONS OF THE AIRFRAME: WING/FUSELAGE INTERACTIONS AND AIRFRAME/ENGINE INTERACTIONS, FOR INSTANCE.

BOTH OF THE EXAMPLES I JUST GAVE SHOWED WORTHWHILE PAYOFF -- BUT ONLY WHEN THE VEHICLE OPERATED FOR A MAJOR PORTION OF ITS MISSION AT ITS DESIGN POINT -- IN THOSE CASES, CRUISE.

MORE SPECTACULAR GAINS IN ECONOMY (AND IN PERFORMANCE) ARE POSSIBLE IF THE DESIGN POINT (THE OPERATING CONDITION WHERE THE VEHICLE IS MOST EFFICIENT) IS VARIABLE IN FLIGHT.

OF COURSE, THAT IS IMPOSSIBLE FOR PRESENT WING DESIGNS, AND SO THE DESIGNER MUST COMPROMISE. THE PENALTY CAN BE MAXIMIZED, BUT IT'S ALWAYS THERE -- AND THE HIGHER THE AIRCRAFT PERFORMANCE: SPEED, ALTITUDE, RANGE, LOAD, -- THE GREATER THE ABSOLUTE MAGNITUDE OF THE PENALTY.

OUR MISSION ADAPTIVE WING PROJECT, PART OF THE ADVANCED FIGHTER TECHNOLOGY INTEGRATION PROGRAM, IS BUILDING A SMOOTH SKIN VARIABLE CAMBER WING TO BE FLOWN ON A MODIFIED F-111.

THE MISSION ADAPTIVE WING IS BEING BUILT BY BOEING IN SEATTLE. IT WILL BE DELIVERED IN MARCH 1982 TO DRYDEN FLIGHT RESEARCH CENTER FOR INSTALLATION ON THE AIRCRAFT. FIRST FLIGHT IS SCHEDULED FOR AUGUST 1982.

WE EXPECT OVERALL FUEL SAVINGS, DEPENDING ON MISSION PROFILE, OF 10 TO 25 PERCENT: WHICH TRANSLATES DIRECTLY INTO DOLLARS, DURING TRAINING AND INTO RANGE CAPABILITY WHEN THE BALLOON GOES UP. THE TURN PERFORMANCE AND BUFFET-ONSET BOUNDARY ARE ALSO IMPROVED.

THIS TECHNOLOGY LOOKS ESPECIALLY PROMISING FOR LARGE, LONG RANGE AIRCRAFT ON A HIGH-LOW-DASH MISSION PROFILE.

THESE EXAMPLES SHOW WHAT WE CAN DO BY MAKING THE AIRFRAME MORE EFFICIENT - AND OF COURSE DOESN'T EXHAUST THE LIST. PERHAPS ONE DAY EVEN BOUNDARY LAYER CONTROL WILL BE FEASIBLE!

WE'RE WORKING ON WEIGHT REDUCTION, TOO. THE PAYOFFS IN REDUCED STRUCTURAL WEIGHT - INCREASED STRUCTURAL EFFICIENCY - ARE SYNERGISTIC: FOR A GIVEN PAYLOAD; LESS STRUCTURAL WEIGHT MEANS SMALLER MEANS LESS DRAG MEANS LESS FUEL AND SMALLER ENGINES, FOR A REALLY SIGNIFICANT IMPROVEMENT. OF COURSE, THE TRADEOFFS CAN BE WORKED THE OTHER WAY - MORE PAYLOAD OR FUEL FOR A GIVEN SIZE, AND SO FORTH.

FIBER REINFORCED COMPOSITE MATERIALS ARE FAMILIAR TO US ALL - WOOD (CELLULOSE FIBERS IN A LIGNIN MATRIX), BONES (CALCIUM CARBONATE FIBERS IN A PROTEIN MATRIX), FIBERGLASS; AND OTHERS MORE EXOTIC: KEVLAR-EPOXY, GRAPHITE-EPOXY, BORON-ALUMINUM, CARBON-CARBON AND MANY OTHERS.

COMPOSITE MATERIALS ARE PRESENTLY IN USE, PRINCIPALLY IN SECONDARY STRUCTURE, ON MANY MILITARY AND CIVIL AIRCRAFT.

THEY SAVE WEIGHT, AND IN SOME CASES EVEN SOME COST, IN THOSE APPLICATIONS, BUT THE REAL PAYOFFS WILL ONLY COME WHEN COMPOSITES ARE USED IN PRIMARY WING AND FUSELAGE STRUCTURE.

ONE STUDY OF A LARGE (BASELINE 500,000 LB. GROSS WT.) AIRCRAFT SHOWED THAT ADVANCED COMPOSITES REDUCED WEIGHT BY MORE THAN 20 PERCENT. ACQUISITION COSTS REMAINED CONSTANT, BECAUSE UNIT COST OF THE MATERIAL WAS GREATER. MOST IMPORTANTLY, OPERATING AND MAINTENANCE COSTS - THE LIFE-CYCLE COST TAIL - DROPPED BY NEARLY A THIRD, PRIMARILY DUE TO REDUCED FUEL CONSUMPTION.

NUMBERS LIKE THAT CAN'T BE IGNORED!

THE TIME FOR COMPOSITE PRIMARY STRUCTURE ISN'T TOO FAR OFF.

WE ARE PURSUING VERY ACTIVE PROGRAMS IN DEVELOPMENT OF COMPOSITE MATERIALS SYSTEMS; DEVELOPMENT AND TEST OF STRUCTURAL CONCEPTS AND COMPONENTS; AND, PERHAPS MOST IMPORTANT AT THIS TIME, IN MANUFACTURING METHODS.

TRANSITIONING REVOLUTIONARY TECHNOLOGY IS ALWAYS HARD, BECAUSE SO MANY THINGS HAVE TO COME TOGETHER, WE THINK WE'RE CLOSE ON COMPOSITES.

JUST WHEN IT LOOKED LIKE THE "WEAVERS AND GLUERS" (NON-METALLIC MATERIALS) HAD THE UPPER HAND OVER THE "HEATERS AND BEATERS" (METALLIC MATERIALS), ALONG CAME RAPID SOLIDIFICATION TECHNOLOGY, AND METALLIC STRUCTURES ARE BACK IN THE ADVANCED AIRFRAME STRUCTURE BALL GAME. (OF COURSE, THEY WERE NEVER OUT, FOR HOT STRUCTURES AND PROPULSION.)

RAPID SOLIDIFICATION - GENERALLY CONSIDERED AS COOLING RATES OF A THOUSAND DEGREES PER SECOND, OR HIGHER - ALTHOUGH THAT DEPENDS ON WHO YOU TALK TO - ALLOWS PRODUCTION OF ALLOYS WITH NON-EQUILIBRIUM COMPOSITIONS: THINGS WHICH JUST WOULDN'T STAY MIXED AT LOWER COOLING RATES, AND IT GIVES A FINENESS AND UNIFORMITY TO THE MICROSTRUCTURE WHICH GREATLY IMPROVES THINGS LIKE STRENGTH AND FRACTURE TOUGHNESS.

AN ADDITIONAL BENEFIT IS THAT THE PRODUCT FORM - A FINE POWDER - CAN FREQUENTLY BE PROCESSED SO THAT THE INITIAL SHAPE IS VERY CLOSE TO THE FINAL SHAPE - LESS MATERIAL TO BUY, LESS SCRAP, LOWER MACHINING COSTS.

THE PAYOFFS FROM THIS TECHNOLOGY - IN WHICH WE ARE ACTIVELY ENGAGED, AND IN WHICH WE EXPECT TO INCREASE ACTIVITY - WHICH BEAR ON ENERGY EFFICIENCY ARE: IMPROVED SPECIFIC STIFFNESS: ABOUT 25 TO 30 PERCENT FOR AN ALUMINUM-LITHIUM ALLOY: INCREASED SPECIFIC STRENGTH: ALSO ABOUT 25 TO 30 PERCENT FOR AN ALUMINUM-LITHIUM ALLOY; AND HIGHER OPERATING TEMPERATURE LIMITATIONS: ALUMINUM ALLOYS UP TO 650°F, TITANIUM ALLOYS TO 900°F.

ALL OF THESE TRANSLATE INTO LIGHTER, MORE EFFICIENT STRUCTURES - WHICH MEANS LESS FUEL CONSUMED BY THE AIRPLANE.

YOU KNOW, THERE IS ANOTHER THING ABOUT RAPID SOLIDIFICATION TECHNOLOGY WHICH I'LL JUST MENTION - SINCE THIS MEETING PRIMARILY ADDRESSES ENERGY - WHICH TRANSLATES INTO FUEL AVAILABILITY (AND COST), IN CONSIDERABLE MEASURE.

IN A LARGER CONTEXT, WE'RE REALLY TALKING ABOUT A CRITICAL MATERIAL - AND PETROLEUM ISN'T THE ONLY CRITICAL MATERIAL BY A LONG SHOT.

ANY HOW, THAT'S THE CONNECTION. THE POINT IS THAT THE RST ABILITY TO PRODUCE NEW, OTHERWISE IMPOSSIBLE ALLOYS CAN HELP REDUCE OUR DEPENDENCE ON CRITICAL MATERIALS LIKE COBALT, CHROMIUM, NICKEL, AND TANTALUM. FOR EXAMPLE, WE CAN MAKE IRON-ALUMINIDES WHICH ARE AS CORROSION RESISTANT AS ORDINARY STAINLESS STEEL AND CONTAIN NO CHROMIUM.

OTHER RAPID SOLIDIFICATION ALLOYS, POSSIBLE REPLACEMENTS FOR THE SUPERALLOYS IN HIGH TEMPERATURE APPLICATIONS, CONTAIN MUCH LESS NICKEL AND COBALT THAN THE ALLOYS PRESENTLY IN USE.

EXCUSE THE DIGRESSION. I WANTED TO MAKE THE POINT - ONE MORE TIME - THAT THE TECHNOLOGY I SPEAK OF TODAY IS NOT LIMITED TO THE ENERGY APPLICATIONS WHICH ARE THE FOCUS OF THIS MEETING. AS ONE WHO FREQUENTLY MUST DEFEND THE TECHNOLOGY BASE AS A WHOLE, I COULDN'T LET THE OPPORTUNITY PASS.

BEFORE I LEAVE THE AREA OF DIRECT SUPPORTING TECHNOLOGY, I'LL GIVE FOUR MORE EXAMPLES.

THE FIRST IS AIRCRAFT SUPPORT SYSTEMS FOR CREW AND EQUIPMENT.

THE OPERATIONAL ENVELOPE AND THE WORLDWIDE DEPLOYMENT ENVIRONMENT REQUIRES THAT THE CREW MEMBER AND THE WEAPON SYSTEM EQUIPMENT ENVIRONMENT BE CAREFULLY CONTROLLED - PURITY, DENSITY, TEMPERATURE, FOR EXAMPLE, OF BREATHING AND COOLING AIR.

MOST PRESENT SYSTEMS USE RELATIVELY LARGE QUANTITIES OF ENGINE BLEED AIR, EXPAND AND COOL IT, CONDITION IT, RUN IT THROUGH THE CONTROLLED ENVIRONMENT, AND DUMP IT OVERBOARD.

OUR STUDIES SHOW THAT CLOSED LOOP ENVIRONMENTAL CONTROL SYSTEMS, WHICH RECYCLE THE CONDITIONED AIR, COULD REDUCE ENGINE BLEED REQUIREMENTS BY HALF, AT A SLIGHT PENALTY IN WEIGHT.

SECONDLY, BETTER FLIGHT MANAGEMENT SYSTEMS CAN REDUCE FUEL CONSUMPTION BY THREE TO FIVE PERCENT.

THOSE OF YOU WHO ARE PILOTS KNOW HOW WE USED TO FLIGHT PLAN (AT LEAST IN FIGHTERS).

- WE WOULD GET THE FORECASTS FROM WEATHER,
- PICK A ROUTE, AND USING THE FLIGHT MANUAL DATA,
- PLAN THE MISSION.

FOR A FIGHTER, THAT WAS IT: MISSION WORKLOADS WOULD NOT USUALLY ALLOW ANYTHING MORE THAN "EDUCATED GUESS" REFIGURING DURING THE SORTIE.

THINGS WERE SOMEWHAT MORE "SCIENTIFIC" ON MULTI-CREW AIRPLANES, BUT DECISIONS AND JUDGEMENTS WERE STILL MADE ON OLD, UNCERTAIN AND AVERAGED DATA.

IDEALLY, WE COULD SENSE EXISTING CONDITIONS - TEMPERATURE, FUEL LOAD, WIND, ENGINE OPERATING CONDITIONS - AND HAVE AN ON-BOARD DIGITAL COMPUTER FIGURE THE OPTIMUM PROFILE FOR WHATEVER THE REMAINDER OF THE MISSION MIGHT BE. THE INFORMATION COULD BE PRESENTED TO THE CREW FOR DECISION, OR DIRECTLY COUPLED INTO THE AUTOPILOT. ALTHOUGH SUCH A SYSTEM IS POSSIBLE, MODIFICATION OF THE ENTIRE FLEET WOULD BE EXTREMELY EXPENSIVE. THE AIR FORCE HAS COME UP WITH A LESS EXPENSIVE OPTION USING COMMERCIALLY AVAILABLE HAND-HELD CALCULATORS PRE-PROGRAMMED WITH FLIGHT MANUAL DATA REQUIRED TO RE-PLAN MISSION PROFILES.

NOW LET'S COME BACK DOWN TO EARTH.

THE THIRD EXAMPLE INVOLVES THE CONSIDERABLE FUEL USED IN AEROSPACE GROUND EQUIPMENT FOR ELECTRICAL POWER, AIR CONDITIONING, AND ENGINE STARTING. MOST OF THE TURBINE POWERED UNITS USE LOW COMPRESSION RATIO, OLD TECHNOLOGY ENGINES.

MEASUREMENTS AND ANALYSIS DONE FOR ONE OF OUR MOST COMMON GAS TURBINE UNITS SHOWS THAT AN EXISTING-TECHNOLOGY RECUPERATOR SYSTEM WOULD CUT FUEL CONSUMPTION BY HALF AT FULL POWER OUTPUT.

AIR FORCE WIDE SAVINGS WOULD AMOUNT TO 8 MILLION GALLONS OF JET FUEL PER YEAR.

FINALLY, I MENTIONED EARLIER THAT THE AIR FORCE'S DAILY FUEL CONSUMPTION IS 38% LOWER THAN IT WAS IN 1973, DUE MAINLY TO FEWER FLYING HOURS. FLYING HOURS WERE REDUCED FROM 4.9 MILLION HOURS IN FY 1973 TO 3.2 MILLION HOURS IN FY 1979. THIS REDUCTION WAS TO SOME EXTENT THE RESULT OF A DECREASE IN THE TOTAL NUMBER OF ACTIVE AIRCRAFT, FROM 10,800 IN FY 1973 TO ABOUT 9,300 IN FY 1979, AND THE USE OF AIRCRAFT SIMULATORS FOR TRAINING. TO MAKE OPTIMAL USE OF AVAILABLE FLYING HOURS, AIRCRAFT SIMULATORS WERE USED TO SUPPLEMENT FLIGHT TRAINING OPERATIONS TO MAINTAIN OPERATIONAL READINESS.

THE DEVELOPMENT OF STATE-OF-THE-ART, HIGH CAPABILITY SIMULATORS, EQUIPPED WITH VISUAL DISPLAY SYSTEMS, IS HELPING TO SOLVE TODAY'S FLYING TRAINING PROBLEM CREATED BY THE GROWING FUEL SHORTAGE, THE PROBLEM IS INCREASED BY THE GREATER COMPLEXITY AND SOPHISTICATION OF HIGH PERFORMANCE AIRCRAFT SYSTEMS, AND THE DECREASED FLYING EXPERIENCE LEVELS OF

CURRENT AIRCREW PERSONNEL. AGAIN, THIS IS ANOTHER EXAMPLE OF TECHNOLOGY WE DO PRIMARILY FOR OTHER REASONS (READINESS AND TRAINING) BUT WHERE WE ALSO ENJOY THE BENEFIT OF FUEL SAVINGS.

THAT MAKES MY POINT: WE IN THE AIR FORCE HAVE A LOT OF THINGS GOING WHICH CONTRIBUTE TO REDUCING OUR ENERGY CONSUMPTION - WE HAVE BEEN DOING THESE SORTS OF THINGS ALL ALONG - AND WE CERTAINLY EXPECT TO CONTINUE.

ENERGY EFFICIENCY IS NOT AN EITHER/OR THING FOR MODERN AEROSPACE SYSTEMS - IT'S AN INTEGRAL PART, AND IS TREATED AS SUCH.

NOW LET ME COME BACK TO THE QUESTION OF FUEL SUPPLY, AND OF OUR ABILITY TO USE WHAT IS AVAILABLE.

WE HAVE A LARGE INVENTORY OF EQUIPMENT THAT WILL CERTAINLY REMAIN IN OPERATIONAL USE WELL INTO THE 1990s, AND, MOST LIKELY, PAST THE TURN OF THE CENTURY.

OUR A-10s, F-15s, F-16s, OUR TRANSPORTS, TANKERS, BOMBERS AND COMMAND AND CONTROL AIRCRAFT ARE DESIGNED TO USE PETROLEUM BASED FUEL.

OUR NEXT GENERATION SYSTEMS, THOSE WE HOPE TO BRING INTO SERVICE IN THE EARLY 1990s, WILL ALSO BE DESIGNED TO USE LIQUID

HYDROCARBON FUELS, THE SAME AS, OR VERY SIMILAR, TO OUR CURRENT FUELS.

THERE JUST AREN'T ANY PRACTICAL ALTERNATIVES.

THAT DOESN'T MEAN, HOWEVER, THAT THERE WON'T BE NEW SOURCES OF FUELS.

QUITE TO THE CONTRARY, WE EXPECT THAT SUCH NEW SOURCES WILL BE DEVELOPED - AND WE ARE HARD AT WORK ON THAT DEVELOPMENT.

OUR EXISTING FLEET, AND NEAR TERM REPLACEMENTS, REPRESENTS A VERY LARGE INVESTMENT - ONE THAT WE HAVE TO MAINTAIN AND PROTECT.

FURTHERMORE, THE COST TO RETROFIT MAJOR HARDWARE CHANGES INTO THIS INVENTORY IS TRULY MIND-BOGGLING.

WE DON'T SEE HOW THAT COULD HAPPEN, FRANKLY.

CONSEQUENTLY, WE MUST ENSURE THAT FUELS MADE FROM NEW - NON-PETROLEUM - SOURCES ARE COMPATIBLE WITH WHAT WE HAVE.

WE SEE SHALE OIL DERIVED FUELS AS THE MOST PROMISING CANDIDATE FOR THE MID TO LATE 80s.

BEAR IN MIND THAT THE AF DOES NOT PRODUCE FUELS - NO WAY - WE'RE STRICTLY A CONSUMER.

BUT WE HAVE FOUND THAT, IN THIS AREA, YOU HAVE TO BE PRETTY KNOWLEDGEABLE, INDEED, TO BE A SMART BUYER.

SINCE TWO OF THE APL PEOPLE WILL PROVIDE YOU WITH DETAILS OF OUR AVIATION TURBINE FUEL TECHNOLOGY PROGRAMS ON THURSDAY, I'LL BE BRIEF.

FOR REASONS I SPOKE TO ABOVE, OUR NEAR-TERM PROGRAM IS STRONGLY ORIENTED TOWARD HARDWARE EVALUATION: WE FOLLOW THE USUAL COMPONENT-TEST, FULL-SCALE ENGINE TEST, FULL SYSTEMS TEST SEQUENCE, USING SYNTHETIC FUELS PREPARED TO CURRENT MIL SPECS.

AFTER THE FULL SYSTEMS TEST, WE PLAN TO DO LIMITED FLIGHT TESTS AND THEN GO INTO OPERATIONAL VALIDATION - ESSENTIALLY, WE'LL RUN ONE OR MORE TYPICAL BASES ENTIRELY ON THE ALTERNATE FUEL, AS A PRELUDE TO MORE EXTENSIVE - OR UNLIMITED - USE.

YOU CAN SUMMARIZE THE SEQUENCE AS R&D, FOLLOWED BY A TRANSITION WE CALL OPERATIONAL VALIDATION AND FINALLY UNCONSTRAINED OPERATIONAL USE.

COLONEL CHARLIE MOORE FROM AIR FORCE HEADQUARTERS WILL DISCUSS OPERATIONAL VALIDATION IN MORE DETAIL THURSDAY MORNING.

THE UNIQUE PROPERTIES OF SHALE OIL AND COAL LIQUIDS: HIGH NITROGEN, HIGH AROMATICS, METAL AND OTHER CONTAMINANTS, FORCE US TO CONSIDER SPECIFICATION CHANGES - HOPEFULLY MINOR - THAT MIGHT BE NECESSARY TO USE FUELS MADE FROM THESE FEEDSTOCKS.

FOR THE LONGER TERM, OUR LABORATORY PROGRAM LOOKS AT WHAT FUEL PROPERTY CHANGES WE WOULD WANT - OR BE FORCED - TO MAKE TO KEEP AN ACCEPTABLE LEVEL AVAILABLE AS WORLD-WIDE ENERGY CONDITIONS CHANGE.

WE MUST BE AHEAD, AND WELL AHEAD, IN THIS AREA BECAUSE SPECIFICATION CHANGES HAVE POTENTIAL IMPACT ON HARDWARE - AND THAT MEANS LONG LEAD TIMES AND POSSIBLY HIGH COSTS.

PLEASE KEEP IN MIND WHAT I MEAN BY LONG-TERM. OUR PRESENT, AND OUR NEXT GENERATION SYSTEMS, WILL HAVE TO BE DESIGNED FOR LIQUID HYDROCARBON FUELS AS WE KNOW THEM TODAY - AND THEN WE WILL HAVE THOSE SYSTEMS FOR TWENTY TO TWENTY-FIVE YEARS, IF EXPERIENCE IS A RELIABLE GUIDE.

SO THE FUTURE FUELS AND SYSTEMS I AM TALKING ABOUT ARE AT LEAST FIFTEEN TO TWENTY YEARS AWAY.

BY WAY OF CONCLUSION, I'D SAY THAT THE AIR FORCE HAS A CLEAR VIEW OF THE ENERGY PROBLEM, PRESENT AND FUTURE, AND IS WORKING IT HARD ON MANY FRONTS:

- CONSERVATION
- ENGINE EFFICIENCY
- MORE EFFICIENT AIRFRAMES
- MORE EFFICIENT SYSTEMS

WHILE PREPARING ALTERNATIVES FOR THE LONG TERM.

WE FIND THE PRESENT POLITICAL, FINANCIAL, AND POLICY UNCERTAINTIES FRUSTRATING, AT BEST, AND POTENTIALLY DEFEATING, BUT REMAIN HOPEFUL.

WE EXPECT DOMESTIC SOURCES FOR NON-PETROLEUM-BASED AVIATION FUELS TO BE AVAILABLE IN THE MID-1980s AND WE INTEND TO BE READY TO USE THEM

I'M CONFIDENT THAT - WITH YOUR HELP - WE CAN MEET THE COMING CHALLENGES.

THE FUEL PROBLEM - OUTLOOK FOR AIR TRANSPORT

Presented by
John G. Borger
Vice President - Engineering (Ret'd)
Pan American World Airways, Inc.
at
Industry-Military Energy Symposium
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Air transportation is highly visible, but still not the largest consumer of petroleum fuels. In 1978, all U.S. transportation consumed some 26% of the total energy produced, of which only 2% was used in the air, 5.8% by buses and trucks, 3.8% by rail, mass and water transport, and 14.4% by private automobiles. Air transportation is growing, to the extent that it has become a major factor in our American way of life. Air transportation will consume more than 11 billion gallons of fuel this year (ATA airlines); the Pan Am share is about 1.2 billion gallons. How much longer this growth continues, and at what rate, depends on the availability and price of fuel.

The transport airplane is wholly dependent on liquid hydrocarbon fuels. With the surge in fuel prices since 1973 (one airline's figures are shown in Slide #1), fuel has become the dominant factor influencing the cost of providing transport by air. Energy effiency of the airplane - usually measured in terms of seat miles, or ton miles per pound of fuel consumed - has steadily improved since introduction of the jets. (Slide #2). The modern jet transport is superior in this respect to the best of the piston transports, and when compared in terms of passengers actually carried, is competitive with surface borne transports.

While the airplane has supplanted most other means of transporting people over longer distances (with the possible exception of the automobile), most air transport fuel is consumed on shorter flights. Slide #3, from data assembled by Boeing, shows that 53% of airline fuel consumed was burned on flights of less than 1,000 miles. Only 16% was consumed on flights of more than 3,000 miles. These are 1978 data; recent trends in the U.S. since adoption of Deregulation may show some changes. The larger airlines have pulled out of many shorter routes, with regional carriers and particularly commuter airlines taking most of these over. Indications are that both these smaller airlines will have much greater growth in the early 80's than the larger carriers. Another important user of aviation fuel is general aviation, which aside from the more obvious pleasure flying, covers pilot training and provides much transportation by business aircraft.

It would be difficult to find a suitable substitute for air transport at this time; even more so in the future. Passenger vessels, other than cruise ships, have almost disappeared. And the passenger train is following rapidly, except for the local commuter train. A B747 carries more than 500 million passenger miles per year. Art Ford of Delta tracked an 88 passenger DC-9 for 33 days last summer. In that time, it carried more than 20,000 passengers on 358 flights over 100,000 miles. Maintenance of the fuel needs for air transportation has become a matter of national interest.

Before '73, fuel costs were about 10% of an airline's <u>total</u> operating costs. Now they exceed 30%. Fuel costs per mile are greater on the shorter flights, less on the longer. In seat mile terms they usually are greater on smaller airplanes, less on the larger; this depends in part on the type of engine used, relative modernity of the airplane, plus other lesser factors.

Although the airlines have been forced to raise fares because of the impact of fuel prices, each operator has exerted considerable effort to conserve fuel and to improve fuel efficiency. Operating techniques have been sharpened by flying slower, higher, and more directly between airports. Carriage of stored fuel has been reduced, climb and descent procedures have been improved, and simulators have been used more for training and six-month pilot checks. Older, less fuel efficient airplanes have been replaced by more efficient types, and the operators have generally succeeded in installing more seats in each airplane and operating with a larger portion of seats filled.

Since the start of the fuel crunch, strong efforts have been made to improve the fuel efficiency of airplanes in service. Some drag reduction modifications have been installed, and much attention has been paid to drag cleanup. Damaged seals are more promptly replaced, misdirected airflows or leakages corrected. We have installed Performance Management Systems in our B747SP's; installation in other B747's is underway. Engine fuel consumption improvements have been incorporated at time of shop visit, and rework standards have been improved with resultant lower fuel consumption when the engine is returned to service. The airlines are indebted to the Air Force for leading the way in use of composites for structures, and for undertaking the KC-135 winglet flight program.

One nagging problem remains: no satisfactory solution has yet been found for engine deterioration; both fuel consumption and exhaust temperature. A freshly repaired engine can be restored to within 1.0-1.5% of its original fuel consumption level as demonstrated on a test stand. Within 1,000 hours after being installed on the airplane, it

deteriorates another 1%, after which it may go another 1.5-2% before it comes off the wing for another shop visit after 3500-4200 total hours. These values are representative of JT9D operation on B747's with a fleet average of some 3-4% deterioration. Other engines will differ slightly; shorter cycle times (average time from takeoff to landing) will reduce time required to reach these levels. We are beginning to learn what causes deterioration but we still don't know what to do about it other than bringing the engines into the shop more often to replace key parts. This can be more costly than the fuel it saves. Some later designed engines show promise of less deterioration. Temperature deterioration accompanies fuel consumption increases. It also has a nasty habit of feeding upon itself. When the engine reaches airworthiness temperature limit, it must be removed for repair.

There is hope for more fuel efficient airplanes in the future. NASA has undertaken an Aircraft Energy Efficiency (ACEE) research program with a target of 45-50% fuel efficiency improvement over airplanes operated in 1975. This program is directed towards changes in aerodynamics, propulsion, structures and materials. Some of the benefits of this program are already apparent, but most will be applicable only to new airplanes and engines coming into service in the mid-80's. Other NASA concepts are rather far reaching, and may not be achievable until much later in the decade. There is some reason to believe that 25-30% improvement can be realized in the next 5-8 years. Improvements realized in service could actually exceed these values, for they do not include allowance for increasing the number of seats per

airplane. The latter has always proven the most rewarding way to increase seat miles per pound of fuel, and also to decrease cost per seat mile.

All of us who have experienced traffic delays on our trips know that these represent wasted fuel. Improvements have been made in Airways Traffic Control (ATC) and airport congestion, but increasing traffic has almost wiped out these improvements. And much remains to be accomplished. I fully appreciate that this is not a simple problem, but much fuel could be saved through reduction of traffic delays.

Forecasting is always risky, but it seems safe to say that growth in fuel consumption will not be as great as that in revenue passenger or cargo ton miles. The new more fuel efficient airplanes will phase in during 1982. Some of the less fuel efficient airplanes have already been replaced. Current replacement airplanes incorporate some fuel efficiency improvements but with two exceptions - the L1011-500 and the DC9-80 - have not included major structural or systems changes required for large increments of fuel efficiency. To date, most of the improvements have been in the engines and increased seating capacities. Some of these probably can be retrofitted. On the other hand airplanes always grow heavier in service, and there have been some regretable weight increases in newly delivered airplanes. I look for continuous improvements in fuel efficiency through the decade. Some of the fallout from the NASA research program undoubtedly will not be retrofittable, thus inspiring another round of airframes and engines.

One problem facing the airlines is the type of fuel to be used. The present standard turbine fuel - designated Jet A - is a "middle distillate" quite similar to fuels used for Diesel engines and for residential heating. While increases in the need for greater supplies of heating oil

may be open to question, it is expected that there will be a shift to greater use of Diesel fuels, particularly for automobiles. Other forms of surface transportation are already large users of this product. The refiners have spent the last 80 odd years in tuning refinery processes to produce more and more motor gas from the crude barrel. Now product demand appears to be shifting, and it is possible that shortages of a particular product may appear during the transition period. This may result in the airlines having to compete more for their share of the barrel than they have in the past.

There is also a problem with crude oil supply: refiners more often are forced to take what they can get. This results in some refineries encountering difficulty in delivering a product that fully meets Aviation Turbine Fuel specifications. Some refiners are urging that relaxing, or broadening the specs would encourage greater production. This is reminiscent of the philosophy behind the development of the spec for JP-4 which was intended to make more turbine fuel available in the event of national emergency. Unfortunately, JP-4 has not endeared itself to the airlines, for its use has been suspected of contributing to at least three accidents.

In the early days, we were told that the turbine engine was rather insensitive to the type of fuel used. Twenty-two years of commercial operation, with another 10-12 years of military background have not fully supported this contention. Current specifications are the result of this experience. There is reason to believe that engines and airplanes could be adjusted to tolerate somewhat less specialized fuels. NASA has initiated a research program to determine whether engines now in service

are receptive to "broad spec" fuels, and if not, what adjustments or modifications would be needed. After the research effort, FAA certification testing is required. Note that the fuel specification is part of the engine manufacturer's Approved Type Certificate. After certification, experience has shown the need for service testing. The modern engine stays on the airplane 4-6-8,000 hours - there have been too many surprises after successful ground tests of much shorter duration to rely on the ground test for complete justification of a fuel spec change. Although there are thousands of engines in service - over 5,500 JT8D's in the U.S. alone, for example - airlines have provisioned spares on the basis of such "on wing times". Encountering a wave of trouble could cause disastrous disruption of schedules; we have an obligation to maintain operating safety. And combustor design is not an exact science. I am reminded of a World War II experience with increasing the end point of Avgas in order to increase availability. In service, the volatility decrease made it necessary to apply carburetor heat when running on lean mixtures, increasing fuel consumption, and negating effects of the spec change.

The specific item most discussed with regard to broadening fuel specifications is Aromatics Content. Along with this goes Smoke Point. The aromatic constituent in fuels burns with a reddish flame, and radiates more heat to the hot section metals. Increased metal temperatures will reduce the service life of these parts, which are usually the most expensive parts in the engine, and already limit the "on wing life" of the engine. Supply of more internal cooling air to these parts would cause more fuel to be consumed and therefore be counter productive. Increases in average aromatic content have already taken place, but these

changes have been relatively small, and have taken place over a long period. To further obscure the effect of these increases, concurrent changes in operating and maintenance practices have been made; thus no overwhelming conclusive evidence is yet available to prove that increased aromatics are good or bad. For example, in the past year we have experienced an increase in JT9D turbine blade failure rate; P&W and we have not been able to conclusively assign the cause, and there is insufficient evidence to place the blame on the fuel.

Programs under way to improve fuel efficiency on future engines are dependent on higher turbine inlet temperatures. The upper limits will be set by the ability of the metals to withstand these temperatures, thus increased radiant heat from the fuel could reduce potential gains. Note also that high aromatic fuels usually have lower hydrogen content, with slightly lower BTU per pound content. On very long flights, this might incur a loss of payload, otherwise it should not be too harmful.

Aromatic fuels tend to produce more smoke, which may give us trouble in meeting emissions requirements. We should also keep in mind that smoke is composed of extremely small particles, which are not too small to cause turbine blade erosion over the time periods noted above.

The above discussion is offered to cite the practical problems in adopting a new fuel of markedly higher aromatic content. There are signs that Diesel engines also do not like fuels with high aromatic content. If these prove out there may be greater incentive for the refiners to control this characteristic. If we have to, I suppose we can find ways to live with high aromatic fuels, but they will not give unmixed blessings.

Most turbine fuel used in the U.S. is Jet A, with a specification freeze point of -40°C. Jet A-I with -47°C freeze point is also produced, particularly for long range operators. Military spec freeze points call for -50°C. Pan Am has not found it necessary to use Jet A-I for its B747 and B747SP operations, which include some of the longest nonstop flights worldwide. Jet A-I is loaded only when nothing else is available; this usually occurs in Europe.

It is claimed that more fuel could be made available if the freeze points requirement were raised. Higher freeze points may require installation of fuel tank heating or recirculting systems in airplanes, particularly the slower versions. Obviously these would add to the cost and operating complexity of the airplane, so if refiners would be willing to share these costs by offering price incentives, I would expect to see such systems on future airplanes.

Some have suggested possible reduction in the Flash Point requirement from the present 38°C. This may run afoul of U.S. and local tax laws, and is of concern because of its possible impact on operating safety, particularly if difficulty is encountered during takeoff at high temperatures.

These and other characteristics such as thermal stability are being studied by NASA. If relaxation of the specification requirements truly would add to the fuel supply without introducing serious new operating problems, the airlines should support the changes. It should be noted, however, that a Boeing study questions whether supply would really be increased.

For the future, there are great hopes that the present liquid hydrocarbon fuels refined from crudes drawn from the early will be replaced

by those derived from coal, tar sands or shale - the so called synthetics. These fuels should be much like fuels presently burned, they could be stored in the present tank farms at airports, and little, if any, changes should be required in the airplanes or engines. The extraction process in each case is not easily accomplished, each will require use of energy, probably from outside sources, and undoubtedly be costly. It now appears that total costs can be competitive and the concept has finally received governmental encouragement.

Synthetic fuel derived from shale appears to be most suitable for use in turbine engines. Some degree of hudrogenation may be necessary in the refining process, and some difficulty may be encountered in meeting freeze point requirements, but otherwise the fuel should be quite similar to that now used. From an airline point of view, full encouragement should be given to development of a plentiful supply of jet fuel from shale. We applaud the Air Force leadership in this program.

Turbine fuels can be derived from coal and tar sands, but the end product shows signs of being high on aromatics and sulphur, and low on heat content. These fuel characteristics appear to be more desirable for auto engines than for aircraft engines, thus it may be preferable to direct fuels from coal or tar sands more towards auto use.

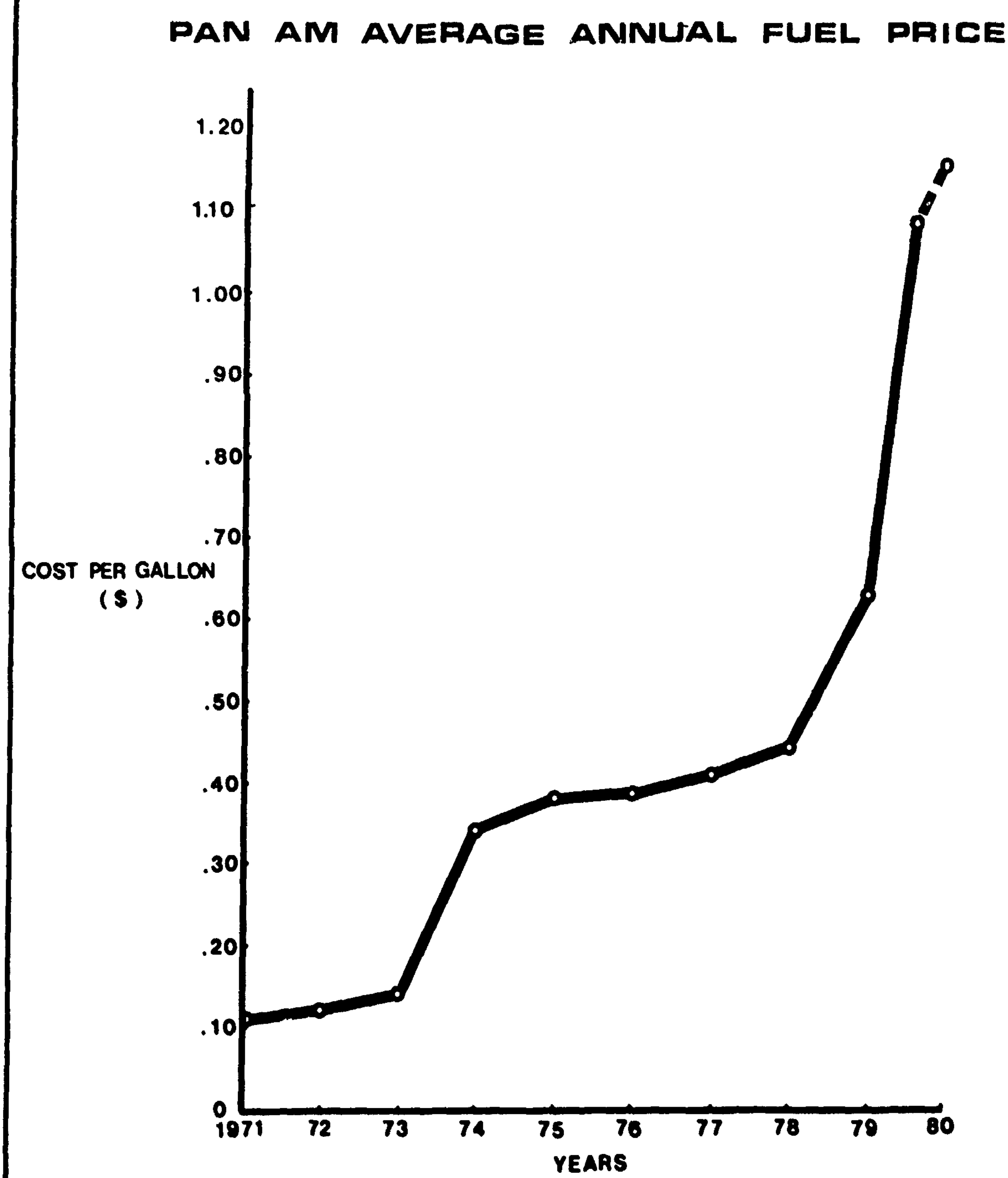
Alcohol shows little promise for turbine engine use - although there may be some opportunity for use in general aviation gasoline engines, where the anti-detonant qualities of alcohol may be helpful. The low heat content of alcohol - less than half of that of kerosine, does not give much hope for its use in turbine engines.

There has been much discussion regarding the proposed use of liquid hydrogen, especially on transport airplanes. Another cryogenic, liquid methane, has also been suggested. While the turbine engines would undoubtedly welcome either of these fuels, particularly hydrogen, entirely new airplanes would have to be built to realize full efficiency from the use of such fuel. Large insulated tanks would be required, but the airplane and engines necessary to accomplish a given mission would be smaller. The airplane literally would have to be built around the fuel tanks.

The greatest problem to be surmounted before using cryogenics is the logistical problem of manufacturing the hydrogen or methane, transporting it to the airport, probably through a pipeline, and then liquifying the gas and storing the liquid at the airport. Perhaps in time someone will find simpler ways of accomplishing the ground logistics. Otherwise much time, energy and money will be required to set up the supply system at all the airports that must be provisioned. It also seems to me that hydrogen would be of greatest benefit to the longer range airplanes and while those of us who represent long range operators would welcome any help we can get, reference to Slide 3 would indicate this to be less productive to the overall picture than aid to the shorter range operations.

If we are to run out of supplies of hydrocarbon fuels, development of the hydrogen airplane refueling system would appear mandatory.

10/20/80

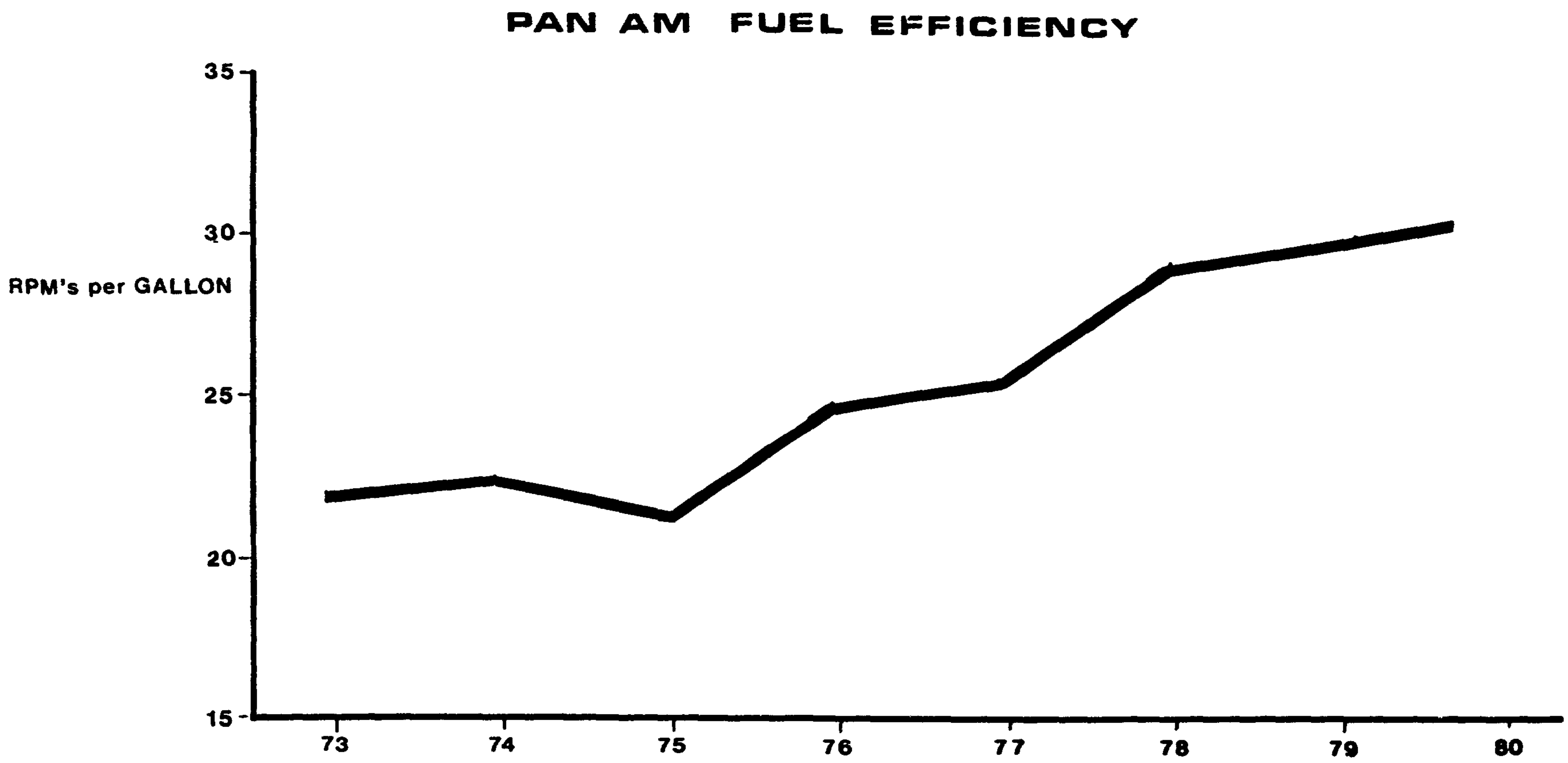


SLIDE 1

PAN AM
Engineering

DATE 10/20/80

SLIDE 2



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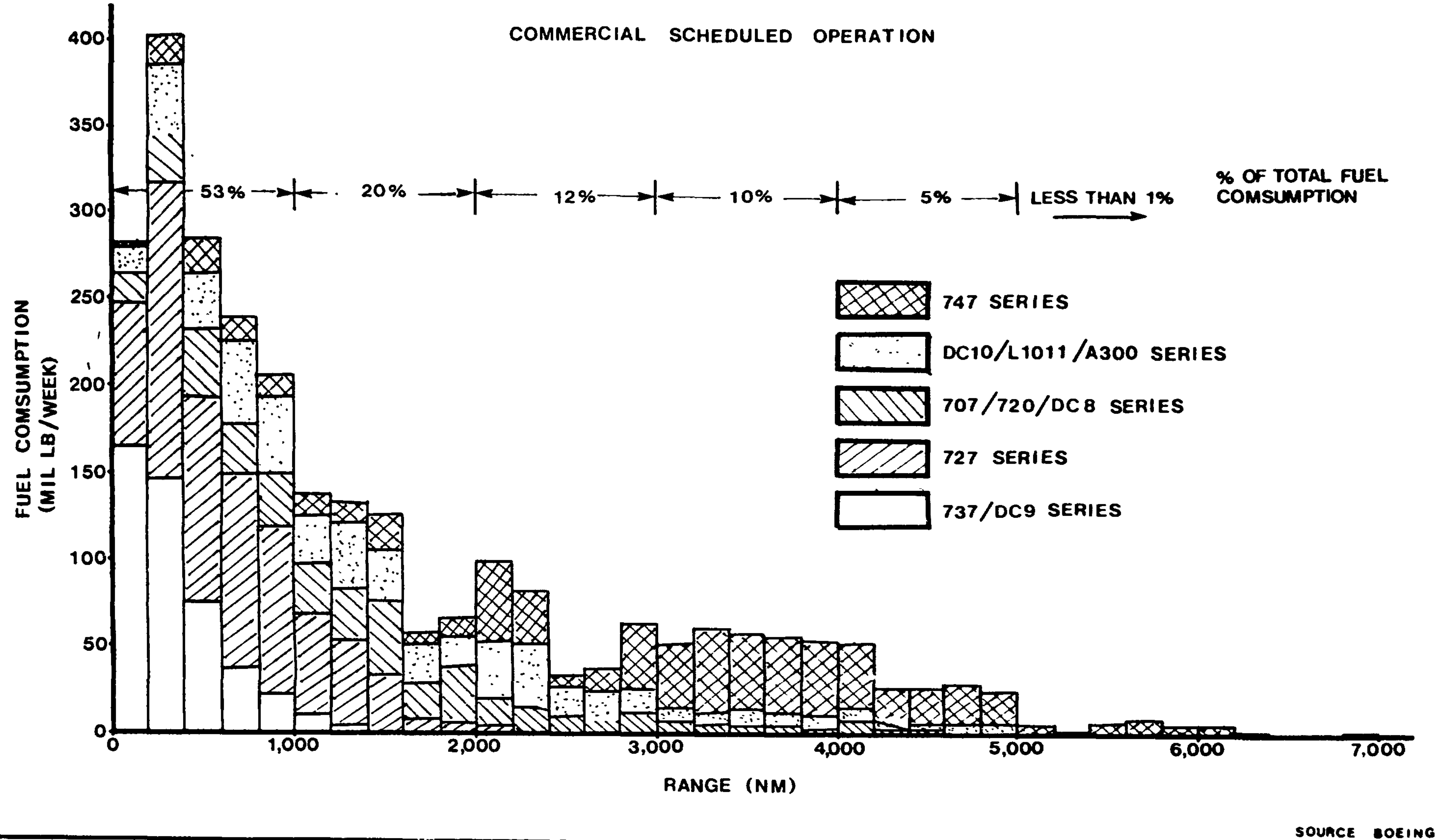
10/20/80

WORLD-WIDE FUEL CONSUMPTION DISTRIBUTION



SLIDE 3

PAN AM Engineering

FUTURE AIRCRAFT ENGINE DESIGN

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SAN ANTONIO, TEXAS

FUTURE AIRCRAFT ENGINE DESIGN

Frank W. McAbee

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It's an honor and a pleasure to have this opportunity to speak to such an outstanding group of Government and industry representatives. Before I start I'd like to share with you a story about the great aviation pioneer, Orville Wright. It seems that Mr. Wright was soundly criticized by a friend for not responding to the rumors that Professor Langley and not the Wright Brothers had made the first flight. "The trouble with you, Orville," said the friend, "is that you are too quiet ... you should assert yourself ... you should talk more." "My friend" answered Orville Wright," the best talker and the worst flier among the birds is the parrot!"

Suffice it to say that I'm not acclaimed as the best pilot in the world ... but please know that I shall keep Orville's response in mind as I talk to you this afternoon about some of the aircraft turbine engine developments that we foresee in the future.

The next generation of gas turbine engines in this century will be far superior to anything that you see flying today. There are, of course, some major challenges that will have to be overcome to make these engines a reality; but we're already beginning

to see the emergence of the technologies and techniques needed to overcome the obstacles.

Before getting specific about the technologies and engines we see in the future, I'd like to talk a bit about the past. In 1903, technology developed by the Wright Brothers was practiced and proven when they made the first successful powered aircraft flight. This technology ultimately changed the face of our world Everyone remembers the Wrights for their contributions to aerodynamics and the control of airplanes, but we sometimes forget that they also designed and built their own engine and propeller. The engine was crude ... but it worked, and was light enough, at 200 pounds, and powerful enough, with 12 horsepower, to fly the airplane.

Technology advances have been used ever since the Wright Brothers' flight in 1903 to improve both airplanes and engines.

The airplane and engine business that started in a bicycle shop 80 years ago spawned an industry that has grown at an average rate of 25% per year, in real dollars, since that first flight. That's nearly 10 times as fast as the rest of the economy. Today our industry is the second largest contributor to the U.S. balance of trade. Today we have operational military aircraft, like the F-15 and F-16, that for the first time can accelerate while in a vertical climb — That's a pretty dramatic feat ... and gives the U.S. Air Force an exceptional tactical advantage.

In commercial air transportation, we've also come a long way from that day in 1925 when the first scheduled passenger flight from Los Angeles carried two passengers 110 miles to San Diego. Today, Boeing 747's routinely carry 325 passengers nonstop from Los Angeles to New Zealand, a distance of 5,664 nautical miles. Technological advances in both the airframe and engine made this progress possible.

So, what do we expect for tomorrow? We in the engine business are working in partnership with our military and commercial customers to anticipate, define, and provide the propulsion needs of the future.

The military indicate a continuing need for increased thrust-to-weight ratio, which means more power from a lighter weight engine and is a prime measure of the level of technology employed in a jet engine. Other military needs include lower procurement and operating costs, and across-the-board improvements in fuel consumption, reliability and maintainability. These needs are not new, of course, but the materials, aerodynamic, and fabrication technology required to achieve them is formidable when we use the performance of today's engines as a baseline.

Working from these basic requirements, we have established for our next generation fighter engine, a goal relative to current technology engines of 4 points improvement in thrust-to-weight ratio, up from 8:1 to 12:1. We plan to achieve significant life cycle

cost reduction by cutting the acquisition and the maintenance cost of the engine each by 25%, and by a 7 to 10% reduction in engine fuel consumption.

To meet our manufacturing cost reduction goals we will use advanced aerodynamic, materials, and structural design technologies to make a dramatic reduction in the number of engine parts. Compared to the engines of today, we plan to reduce the number of parts by approximately 60%. This will significantly reduce engine weight and purchase costs and will also reduce engine maintenance costs.

The application of advanced manufacturing technology is an area in which we have been working very aggressively, and which contributes significantly to cost reduction by decreasing manufacturing time and labor. In the forefront is the increasing use of computer-controlled machinery and automated manufacturing processes. This is a technology unto itself, and the payoff possibilities here are almost endless.

An associated area of great potential is the use of advanced manufacturing processes to reduce raw material requirements. Typically, we start the manufacturing process for a large turbofan engine with approximately 50,000 lb of material to produce an engine that weighs about 8,000 lb. The 42,000 lb difference ends up as metal chips and we are making good progress in lowering this ratio. For example, several years ago it required 390 lb of

metal to produce a 113 lb turbine disk. Now, by using advanced forging processes, only 230 lb of material — 160 lb less, — produces the same finished disk. That's a 41% reduction in raw material requirements. Since we depend on strategically vulnerable sources of supply for many engine materials, like cobalt, manganese and chromium ... the significance of this saving goes beyond just reducing the cost of the engine. And no less importantly, using fewer parts and more efficient manufacturing methods to make the parts, we will see a reduction in manufacturing plant energy consumption for a comparable level of production output.

Reduction in the number of engine parts will be a major contributor in achieving increased engine thrust-to-weight ratio since the total engine weight is reduced. However, the most significant contribution toward meeting this goal will come from increasing the engine operating temperature. Using new high-temperature alloys and new manufacturing techniques, we will achieve higher operating temperatures for critical engine parts like the combustor and turbine, while, at the same time, extending part life from the current three years to 10 years for comparable usage.

The application of advanced materials such as carbon nozzles and graphite polyimide fan cases will further contribute to reducing engine weight and maintenance cost.

Our goal of a 7 to 10% reduction in fuel consumption, will come primarily through improved component efficiencies combined with higher levels of turbine temperature and higher overall engine compression ratios.

Another area which will contribute dramatically to engine cost and weight reduction is the development and application of full authority digital electronic engine controls. This technology promises very large payoffs in weight, cost, and overall engine performance. We're currently using electronic controls on a partial authority basis on operational engines. In the future we believe that electronics will provide all the engine control functions. Today our advanced work is well along toward proving that belief. These controls will not only have the capability to maintain the engine at optimum operating levels, while monitoring engine health and safety limits, but will also communicate with flight control and airframe systems.

In combination, the technology improvements I have just mentioned will result in an engine which is 25% less expensive to buy and maintain, which is 25% lighter and burns 7-10% less fuel for a given level of thrust.

Now, let me turn away from technical specifics and talk for a moment about engine development philosophy for the future.

In the early days of powered flight, engine performance capability and availability were the predominant factors in the design and development of advanced performance military and commercial aircraft.

As engine development became more expensive and required longer periods of time, we got away from that approach and leaned more toward concurrent airframe and engine development. This approach caused problems.

Today, industry and military planners are working to study and define the future systems characteristics that may ultimately emerge as requirements. Jointly, we are projecting across the board needs for fighter, interceptor, bomber, transport, and general purpose aircraft.

If money was of no concern, we could design and develop new engines optimized for each projected application. Obviously, that's too expensive a way to go and the country simply can't afford it. In an effort to find an acceptable compromise, we and the DoD have jointly conceived and developed an approach which has the potential for providing mature advanced-technology engines when they are needed for new aircraft designs in a cost effective manner. It is called MACE.

MACE stands for *Mulitple Application Core Engine*, a new approach to engine development. With this concept one or more multipurpose advanced-technology engine cores, in basic thrust

size categories will be developed. These cores, when combined with a particular fan, augmentor or other performance options will meet the specific engine requirements of the projected weapon system. Achieving maturity in the core is the most demanding part of engine development and should preceed development of a complete engine by 2-3 years.

In a practical sense, we will establish the demonstrated technology base for a new family of engines of varying size and performance characteristics which stem from the developed and tested common core. This approach has the potential for providing advanced technology, cost-effective engines without the necessity of a new engine start for every new aircraft.

In my remarks today, I have discussed our needs-oriented advanced technology programs. I don't want to leave you with the impression that all our work is going into developing advanced engines. We are continuously working to incorporate our advanced technology into current engines to improve their performance, energy efficiency, maintainability and reliability. Also, as the technology is ready and as the need is apparent, we create newer models of our existing engines. In today's highly competitive environment, we can't let this new technology sit idly on the shelf until it can be used in a totally new engine system.

As engine designers and builders we are very concerned with energy conservation programs. We seek out and employ effective

conservation practices in the operation of our manufacturing facilities. We also make significant contributions to the conservation programs of engine users by developing new engines which are more energy efficient and by modernizing engines in service to reduce their fuel consumption.

So, what does the gas turbine engine picture look like for the next generation? I see a strong needs-oriented industry-wide advanced technology program which is jointly supported by the government and industry. I also see huge challenges in military preparedness and air superiority. On the one hand we need to design and build the most superior aircraft in the world. On the other hand, we must continue to strive for much better fuel efficiency, lower cost, reliability and maintainability. It simply won't do — to achieve one without the other.

As the twenty-first century approaches, let's reflect again on the Wright Brothers and the almost unbelievable things which have happened in our lifetime. I'm not smart enough to tell you what is going to happen in the next hundred years, but I do know that technology represents a prudent investment in future military readiness and will progressively open our eyes and audaciously lead us through the doorway to that future.

Thank you!

DOD FUEL REQUIREMENTS AND SUPPORT

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21-23 OCTOBER 1980
SAN ANTONIO, TEXAS

DOD FUEL REQUIREMENTS AND SUPPORT

BGEN LAWRENCE R. SEAMON

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BGEN Seamon discussed the changing nature of the world petroleum market during the preceding decade, and the associated effects on DFSC's procurement and supply mission.

Since the time of the Embargo, DFSC has been in a position to observe first hand the evolution of a new world petroleum industry market structure. Major buyers of petroleum products, have been forced to adjust to a market that is being increasingly controlled and dominated by national governments at both the consuming and producing ends.

DFSC's procurements have been seriously affected by supply interruptions, such as the Arab Embargo, and shortages developing in the wake of the Iranian crisis. In the past, the Department of Defense has typically dealt with spot shortages with conventional techniques such as supplemental procurements, inventory drawdowns, and as a last resort, relief under the Defense Production Act.

DFSC recognizes that the petroleum market is basically unstable and potentially volatile, due to the emerging prominence of political considerations coupled with the economic fretan of supply and demand. DFSC is therefore taking a number of important steps to adjust to the new market realities of the 80's. The basic thrust of these new initiatives is to develop stable, long term supply sources. For example, DOD concluded an agreement with the Department of Interior which will

give DFSC access to Outer Continental Shelf royalty crude oil. DFSC intends to exchange this crude oil with small refiners for DOD mobility fuels.

Another initiative DOD is taking involves Synthetic Fuels Development. DFSC expects to fill a substantial portion of DOD fuel requirements in the late 1980's from the developing synthetic fuels industry.

STRATEGIC PETROLEUM RESERVES

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SAN ANTONIO, TEXAS

Strategic Petroleum Reserve Briefing

(Slide 1) The interruption of petroleum supplies during the winter of 1973 - 1974 demonstrated to the United States the need for an emergency storage program. The resulting petroleum shortage caused severe economic impacts on the United States economy and emphasized its vulnerability to interruptions in imports from major oil exporting nations.

(Slide 2) As a result of this interruption, the United States Congress passed the Energy Policy and Conservation Act (EPCA) in December of 1975, which required that a Strategic Petroleum Reserve be established.

(Slide 3) The EPCA authorized the storage of up to 1 billion barrels of oil to diminish U.S. vulnerability to supply disruptions. This is the first time the creation of a Strategic Petroleum Reserve of this size was undertaken.

(Slide 4) Just to give you some idea of the enormity of the Strategic Petroleum Reserve storage goal - one billion barrels of oil would fill the Superdome in New Orleans 45 times.

(Slide 5) The Strategic Petroleum Reserve will reduce vulnerability in the event of a severe petroleum supply interruption by limiting economic impact. GNP losses of $40 to $100 billion could be avoided during a severe OAPEC interruption. The Reserve will increase foreign policy flexibility by allowing more time to resolve the cause of an embargo prior to a severe impact and will reduce military

vulnerability. The SPR may help deter an interruption by imposing substantial revenue losses on embargoing countries before an embargo seriously impacts the United States.

(Slide 6) Although the EPCA included a target of 500 million barrels of crude oil and petroleum products in storage by the end of 1982, SPR Plan Amendment No. 1, in May 1977, accelerated that target date to 1980. SPR Plan Amendment No. 2, submitted to Congress in May 1978, increased the goal of the Reserve from 500 million barrels to 1 billion barrels by 1985 and provided for implementation of a 750 million barrel Reserve by that date. Decisions were to be made at a later date on the composition of the last 250 million barrels of protection.

When it became clear that these ambitious goals were not achievable and that facilities development costs and technical problems had been significantly underestimated, the Department of Energy re-examined the initial schedule assumptions. Stewardship Report No. 2 set as a fill target 250 million barrels by June, 1980, 500 million barrels by October 1983 and 750 million barrels by 1986.

The baseline fill targets were technically achievable by 1980, but the world crude oil market disruptions precluded accomplishing the storage goals. In January, 1980, the President's FY 1981 budget forecast fill goals of 250 million barrels by December 1982 and 750 million barrels by October 1989.

(Slide 7) The total cost of the SPR program is estimated at $40 billion. The program is currently being developed in three phases. Phase I, consisting of 248 million barrels of oil in storage, is estimated to cost $886.3 million or $3.57 per barrel. Phase II, consisting of 290 million barrels of oil is estimated at $702.3 million or $2.42 a barrel. Phase III, consisting of 212 million barrels, will cost an estimated $1.03 billion or $4.88 a barrel. The average cost for the first 750 million barrels is $3.49 a barrel. Phase I distribution capability is 1.7 million barrels a day. At the completion of Phase II SPR response will be increased to 3.5 million barrels a day and with the completion of Phase III total drawdown capability will be 4.5 million barrels a day.

(Slide 8) A number of Department of Defense agencies support the Department of Energy in its development of the Strategic Petroleum Reserve. The Defense Fuel Supply Center (DFSC) acts as an oil purchasing agent for DOE. Defense Contract Administration Services (DCAS) provides quality assurance services at discharge

ports. The Military Sealift Command (MSC) arranges ocean transportation for FOB origin oil purchases.

(Slide 9) Certain fundamental requirements to fulfill the implementation of the Strategic Petroleum Reserve were apparent at the outset. These requirements were translated into the criteria which were used for storage technique selection and site selection. Each one of the identified storage alternatives was evaluated in accordance with the following criteria:

1. Technical feasibility and suitability for storage. Potential storage sites had to be structurally sound, assuring the containment of the oil.
2. Storage capacity availability. Storage facilities had to have adequate existing capacity to meet the short term requirements (the 250 million barrel goal) and total potential capacity must contribute to the remaining program requirements.
3. Proximity to existing petroleum distribution systems. Distribution of stored petroleum is cost sensitive to distance from major crude oil pipelines or ports. Maximum use of the existing distribution

systems in the United States is essential for the effective distribution of the reserve.

4. Costs. Facility types were evaluated on the basis of their relative costs of acquisition, development and operation.

5. Environmental impacts. Each type of candidate storage structure and site was evaluated in terms of the potential environmental impact that would result if used for the storage program, and our ability to obtain necessary permits for the activity.

6. Economic impacts. Development of a particular facility should have no long-term negative economic impact including loss of employment.

7. Security and safety. Alternative facility types were evaluated for their security from fire, natural disaster, sabotage, and other factors which might affect their security and safety.

(Slide 10) Salt domes with existing storage in the Gulf Coast area were selected based on these criteria. The storage had been created by petrochemical firms

by solution mining with water in order to create brine as feedstock and by companies which mechanically mined salt. These salt domes were in close proximity to major distribution systems. The sites selected included Bryan Mound in Texas, and West Hackberry, Sulphur Mines, Bayou Choctaw and Weeks Island, which are located in Louisiana.

(Slide 11) The sites are grouped and identified by proximity to major crude oil distribution centers. A large portion of all crude oil entering the United States enters through the Gulf of Mexico and is transferred inland through pipelines. The SPR sites are interconnected with three major pipelines, Seaway, Texoma and Capline. Crude oil can be distributed during an emergency through these and other interconnecting pipelines, through local pipelines serving refineries and by ocean going tanker for distribution to other locations not served by these pipelines, such as the East Coast of the U.S.

(Slide 12) The fundamental technique of cavern development begins by exposing salt to raw water. This is accomplished by drilling a borehole and injecting raw water. The water is then allowed to dissolve the salt and the resulting brine is removed from

the hole. As the salt dissolves, the hole enlarges, forming a cavity. Various solution mining techniques allow control over cavity shape and expedite development.

(Slide 13) During leaching, fresh water is pumped into the cavity, and brine is removed. For each barrel of storage space created, seven barrels of fresh water must be injected and seven barrels of brine disposed. When oil fill occurs, oil is injected into the cavern resulting in a barrel for barrel displacement of brine. To withdraw the oil fresh water is injected to displace the oil.

(Slide 14) Three stages of development during solution mining are shown here: drilling and chimney development, direct leaching and sump development, and reverse leaching and shaping.

(Slide 15) The three well cavern concept was the baseline design selected to achieve the original demanding SPR fill schedules. Early studies indicated that the tri-lobe technique promoted faster leaching and expedited the availability of usable storage space for fill. When available storage space was no longer a constraint a one-well concept and a two-well slickhole concept were adopted over the three well design to reduce capital and operating costs.

(Slide 16) Three methods of brine disposal were considered - (1) commercial sale; (2) deepwell injection into underground aquifers; and (3) disposal in the Gulf of Mexico. On each of the sites, other than the conventionally mined site, brine is being disposed of by injection into wells. To accommodate leaching of new wells at Bryan Mound, and West Hackberry, such large amounts of brine are being produced, the only practical way to dispose of it is to pump it into the Gulf of Mexico.

(Slide 17) Bryan Mound is located in Brazoria, Texas. It is 3.6 miles from the Seaway docks which you can see in the upper right and 4.6 miles from the Seaway pipeline in the upper left corner of this slide. A brine line to the Gulf of Mexico in the lower left has been completed and is currently operating at the design flow rate of 680 MBD. Bryan Mound has 60 million barrels of capacity and is being expanded by another 120 million barrels in Phase II. A further expansion of 40 million barrels is planned in Phase III. After the Phase II and III expansion Bryan Mound would have a capacity of 220 million barrels. During an emergency, oil can be shipped from Bryan Mound through the Seaway pipeline into the Mid West, or loaded into tankers at the Seaway and Phillips Oil Company docks.

(Slide 18) This aerial of the Bryan Mound site shows the four oil storage tanks, brine holding ponds, expansion area and other site facilities.

(Slide 19) Oil is first discharged by tanker at the Seaway docks. Oil may also be pumped to the docks for loading onto tankers during drawdown.

(Slide 20) The oil is pumped from the Seaway Docks to these tanks at the site.

(Slide 21) These are typical motor-operated manifold valves at the sites, regulating flow through underground manifolding.

(Slide 22) Through the underground manifolding, the oil is then pumped into caverns.

(Slide 23) This photo phows a typical pump station at Bryan Mound.

(Slide 24) Oil is injected into the storage caverns through wellheads and brine is removed.

(Slide 25) Brine is pumped through oil/water separators, then to brine holding ponds where the brine settles before being discharged 12.5 miles into the Gulf of Mexico.

(Slide 26) The fresh water intake structure on the Brazos River is used during the leach/fill and withdrawal processes. It is currently capable of delivering one million barrels a day of raw water into the system.

(Slide 27) Anhydrite removal is a problem in the early stages of leach-fill. Here anhydrites are shown collected in a separator.

(Slide 28) An in situ data acquisition system named BRIMS (for Brine Measurement System) was deployed at the Bryan Mound brine diffuser to enhance operational control of the brine disposal system and to complement shipboard oceanographic monitoring of brine disposal.

BRIMS consists of a diffuser flow meter, an oceanographic current meter and an array of bottom-mounted salinity and temperature sensors all of which are hard-wired to a large telecommunications buoy. Signals from the suite of instruments are electronically processed at the buoy and radioed to the storage site where a data processing system computes, stores and displays data of brine plume distribution and orientation at the ocean bottom and relates it to rate of discharge, ambient

salinity and temperature and ambient current speed and direction. Data are continuous and in real time and are accessed by DOE, NOAA and EPA by telephone.

(Slide 29) Site chemists are an important element of the program to monitor oil quality, and perform analysis of brine and site effluents.

(Slide 30) Each site has fire equipment and trained personnel in case of an emergency. Each site has a foam truck specifically designed for the SPR fire water systems, portable foam generators and tank cooling systems.

(Slide 31) West Hackberry salt dome is located in Cameron Parish, Louisiana, about 18 miles south of the town of Sulphur. This site is connected with the Sunoco Nederland terminal & Texaco pipeline via a 45 mile 42" crude pipeline. The site has 51 million barrels of existing capacity. The site will be expanded by an additional 160 million barrels during Phase II and 30 million barrels in Phase III, for a total capacity of 241 million barrels. When the expansions are completed, oil can be withdrawn from the site at a rate of 1.4 million barrels per day.

(Slide 32) This is an aerial shot of the West Hackberry site.

(Slide 33) This is a shot of a typical control room which permits remote operation, monitoring and data collection.

(Slide 34) Meter stations are used for oil measurement at the sites.

(Slide 35) In April, 1980 the Department of Energy successfully withdrew approximately 1.4 million barrels of crude oil from Bryan Mound, Bayou Choctaw and West Hackberry. The operational readiness exercise was conducted to demonstrate the physical capability of the SPR to drawdown crude oil in a simulated crude oil supply interruption. At West Hackberry, fresh water was pumped from the nearby Intercoastal Waterway at a rate of approximately 500,000 barrels per day, which is then pumped under pressure from the holding pond into the underground salt cavern to force the oil out of storage.

(Slide 36) Drilling for the Phase III expansion is currently underway. Pictured here a total of 16 single well caverns are being drilled.

(Slide 37) Sulphur Mines is located in Calcasieu Parish, Lousiana, approximately 20 miles north of the West Hackberry site. This is the smallest SPR site with a capacity of 22 million barrels. The site is connected to the West Hackberry/Nederland pipeline by a 16" 17 mile pipeline. This site operates as a satellite of the West Hackberry site.

(Slide 38) This slide shows Sulphur Mines from an aerial view.

(Slide 39) A closer view of Sulphur Mines shows the brine holding ponds, pumps, water tank and electric power sub-station.

(Slide 40) Over 200 miles of 36" and 42" pipeline have been constructed to date. The photo shows a pipeline staging area.

(Slide 41) This is the 42" diameter, 42 mile pipeline connecting the West Hackberry site to the Sunoco Terminal.

(Slide 42) The pipeline from St. James to Weeks Island is shown being placed in a ditch on the eastern side of the Atchafalaya Basin.

(Slide 43) In laying down the St. James to Weeks Island pipeline, the Atchafalaya Basin had to be crossed.

(Slide 44) This is the laydown barge with the welding station in another picture of the Atchafalaya Basin crossing.

(Slide 45) Here, a "pig" is being taken out at West Hackberry after a successful testing of the 42-inch pipeline.

(Slide 46) Presently, the brineline to the Gulf of Mexico is being laid at Holly Beach as part of the West Hackberry expansion program.

(Slide 47) At St. James, the Louisiana Capline is served by the Bayou Choctaw and Weeks Island sites.

(Slide 48) Oil can also be distributed through the DOE's St. James Terminal. This terminal consists of a 2 million barrel tank farm and 2 docks on the Mississippi River. It is located adjacent to and is interconnected with the Capline, LOCAP and Koch terminals.

(Slide 49) The facility includes six storage tanks, two docks, and associated pumps, piping and electrical equipment.

(Slide 50) The Zapata Ranger completed a successful docking during the initial shakedown testing of the docks.

(Slide 51) Bayou Choctaw is located in Iberville Parish, Louisiana, approximately 20 miles southwest of Baton Rouge, and about 35 miles northeast of St. James terminal on the Mississippi River. This site has a 36 million barrel capacity and will be expanded by 10 million barrels in Phase II. After expansion, this site will have a withdrawal capability of 480 thousand barrels per day.

(Slide 52) This aerial shot of Bayou Choctaw shows the pumping station, storage wells, warehouse and control room facilities, brine holding ponds, raw water intake structure and other site facilities.

(Slide 53) Here is a close up shot of a pump station.

(Slide 54) This concrete well pad over well #19 shows DOE concern to protect swampland environment.

(Slide 55) This oil skimmer is an example of oil spill clean-up equipment used by the SPR.

(Slide 56) Weeks Island is the only conventional mine. The site is located on Vermillion Bay in Iberia Parish, Louisiana.

(Slide 57) The Weeks Island salt dome is roughly circular is shape. Useable storage capacity in the mine is 750 million barrels. The 10-foot service shaft will be used for the pump shaft. Oil fill will be through lines in the shaft. Oil will be withdrawn by submersible pumps located at the base of the service shaft. Morton salt operated this two level room and pillar mine since 1903 and supplied salt to the nation for almost a century.

(Slide 58) This aerial shot looks over SPR site facilities toward Morton Salt Company in the background.

(Slide 59) Workers on these drill rigs are shown sinking the holes used for fill at Weeks Island.

(Slide 60) This is a typical mammoth cavern in the upper level of the two level mine.

(Slide 61) During construction sections of heavy equipment were welded together for conversion work.

(Slide 62) To prevent undue vapor pressure buildup and hydrocarbon loss during filling or normal operations, vapor recovery system was installed.

(Slide 63) If a severe oil shortage were to develop tomorrow, our oil in the ground could be on

its way to the nation's refineries at a moment's notice. The EPCA authorizes drawdown of the SPR when the President determines there is a 'severe energy supply interruption' that

a. Is or is likely to be of significant scope and duration, and of an emergency nature,

b. May cause an adverse impact on national safety or the nation's economy, and

c. Results, or is likely to result, from an interruption in the supply of imported petroleum products, from sabotage or an Act of God.

(Slide 64) Drawdown can occur after a Presidential finding and only in accordance with the SPR plan.

(Slide 65) The current Drawdown Plan permits the auction sale of crude oil to refiners. The sale of oil also may occur through the regulatory process under the existing Buy/Sell Program, under the Standby Mandatory Crude Oil Allocation Program or a special crude oil allocation

program established specifically for the SPR. Quantities and prices will be determined at the time of the drawdown. Oil can also be allocated to meet a special need, for example, a DOD shortfall or a regional shortfall.

(Slide 66) The latest policy development in the Strategic Petroleum Reserve Program occurred with passage of the Energy Security Act. Under the Energy Security Act, the Department of Energy must fill the Reserve at a minimum rate of 100,000 barrels per day or shut in the Naval Petroleum Reserve. We began filling the Reserve in September at 100,000 barrels per day and hope to increase that rate in the future.

(Slide 67) The Strategic Petroleum Reserve has been a big undertaking and a big challenge, but the program is moving ahead and does give us some insurance in case of a supply interruption .

PROPULSION TECHNOLOGY

PRESENTED BY

GERHARD NEUMANN
VICE PRESIDENT AND GROUP EXECUTIVE (RETIRED)
GENERAL ELECTRIC

PRESENTED TO THE
INDUSTRY-MILITARY ENERGY SYMPOSIUM
21-23 OCTOBER 1980
SAN ANTONIO, TEXAS

PROPULSION TECHNOLOGY

(Emphasizing Energy and Fuel Savings)

1. Definition of Propulsion Technology

   - Design for Peace or for War?
   - Design for Transport or Fighter?

2. Design for Life Cycle Costs or to Win a Contract?

3. Design for Maximum Efficiency, Lowest Weight, Smallest Diameter, Lowest Cost of Development and also Production?

4. Design for Manufacturability and Maintainability?

5. Experiences Gained during YF16 vs. YF17 Competition?

6. Maintain Guaranteed Performance for Life of Propulsion System?

7. Keep Repairability in mind?

8. Keep Critical Materials - such as Cobalt and Chromium - or "Ersatz Materials" in mind?

9. We have come a long way in 40 years . . . . .

10. Low SFC in Test Cell doesn't necessarily mean Less Fuel Burned! Weight Increase for Mixer, etc., may well offset SFC Gain (Gen. Gerrity).

11. Life Cycle Fuel Burned must be Maintainable after O/H.

12. If Everything Goes Well - (and it rarely does), We Can Expect 15-18% Fuel-Burned Improvement by the End of 1990's, Including Engines.

13. "12" Will Require (Namely):

    - Higher Engine Component Efficiencies
    - Higher Cycle Bypass Ratio
    - Integrated Aerodynamics of Nacelle, Wing, Pylon - Inlet and Exhaust
    - Integrated Electronics
    - Lighter Materials - Structural Rearrangements
    - Broader Fuel Specs
    - Improved Operating Techniques

14. Turboprops?

15. P.S.

    TWA 'Ambassador' Magazine, reduction from 3 copies to 1, per seat, saves $343,000/year.

22 October, 1980

GENERAL SESSION, CONTINENTAL ROOM OIL SPILL CLEANUP TECHNIQUES

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1980 MILITARY - INDUSTRY ENERGY SYMPOSIUM

DEPARTMENT OF THE AIR FORCE

SAN ANTONIO, TEXAS

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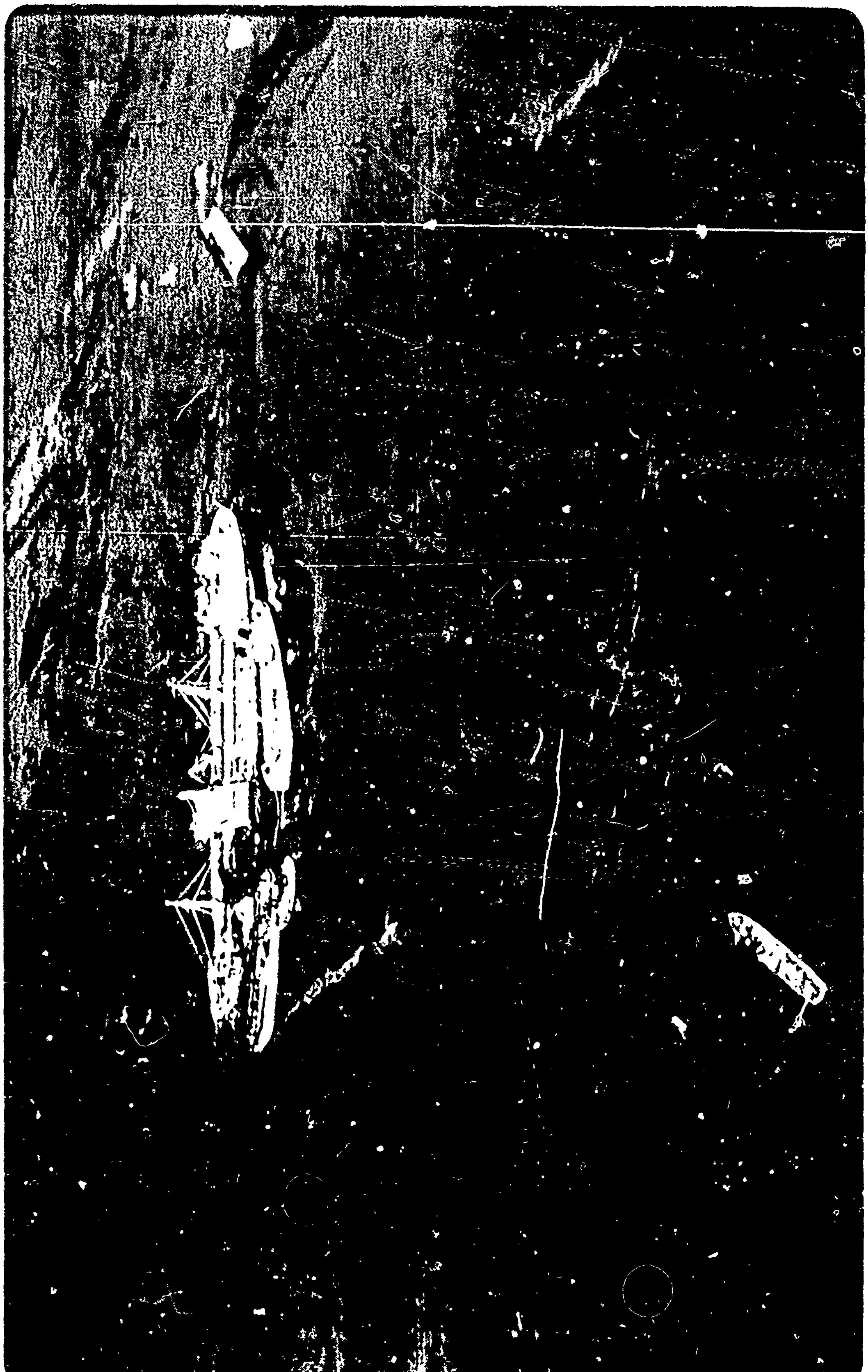


INTRODUCTION:

This briefing proposes that the subject of oil spills and their control is of more vital national and international interest now than at any time since the 1969 Santa Barbara Channel accident. Almost every day, this subject makes the newspaper headlines. Greater coverage by the print and electronic media is obviously due to increased public awareness, more widespread and regular satellite surveillance and a general increase in enforcement of ocean law. The dependence of Western nations on imported oil has sharply focused public attention on the technological causes of oil spills - e.g., the aging of tankers, the extreme increase in displacement of new super-tankers and greater density of petroleum transport traffic. It must be remembered, however, that, while technology has brought us the "oil spill", technology can also prevent it or control it and remove it before it damages our environment. The thrust of this briefing is:

1. To examine certain areas of improved technology;
2. To project the effect of such technology on various kinds of spills.

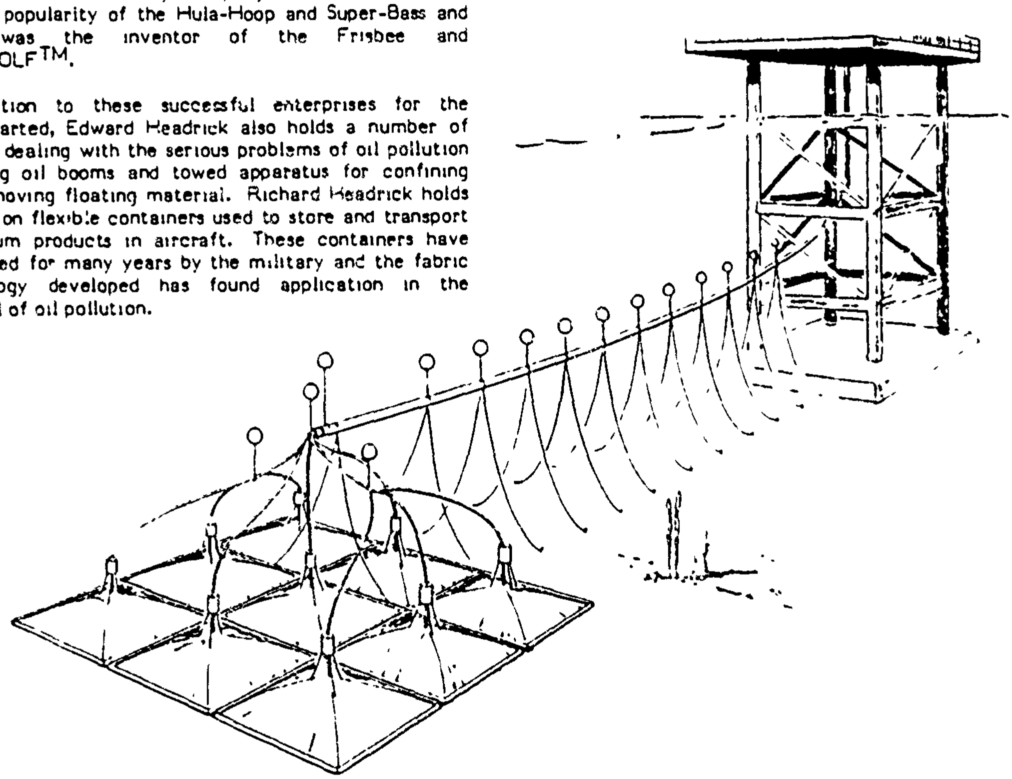
HISTORY:

For the purpose of this briefing, we will restrict ourselves to our own technology which we know best, providing photographic evidence of its effectiveness. This technology was developed by Richard and Edward Headrick, whose inventions range from the toy and recreation industry to the defense and the offshore oil industries. Edward Headrick was Executive Vice President of Wham-O-Toy Company and was responsible for the popularity of the Hula-Hoop and Super-Bass and later was the inventor of the Frisbee and DISC-GOLF™.

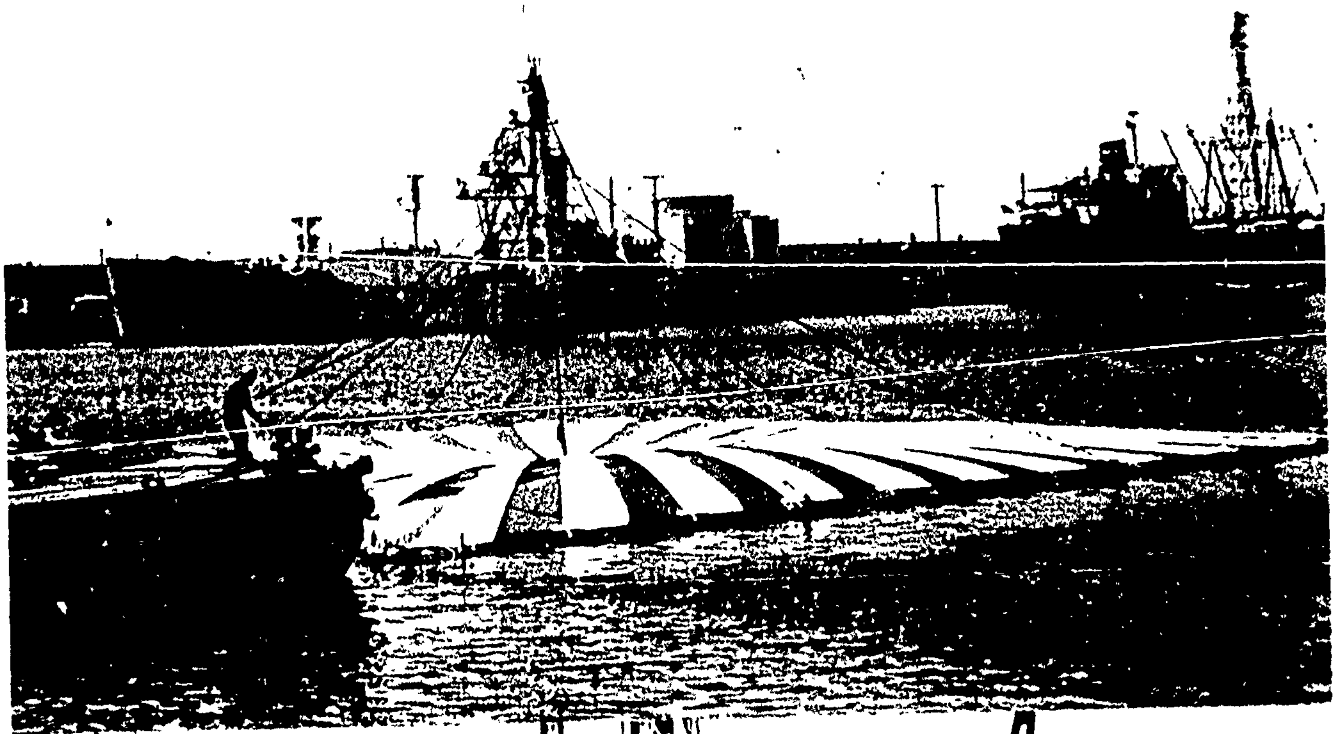
In addition to these successful enterprises for the light-hearted, Edward Headrick also holds a number of patents dealing with the serious problems of oil pollution including oil booms and towed apparatus for confining and removing floating material. Richard Headrick holds patents on flexible containers used to store and transport petroleum products in aircraft. These containers have been used for many years by the military and the fabric technology developed has found application in the removal of oil pollution.

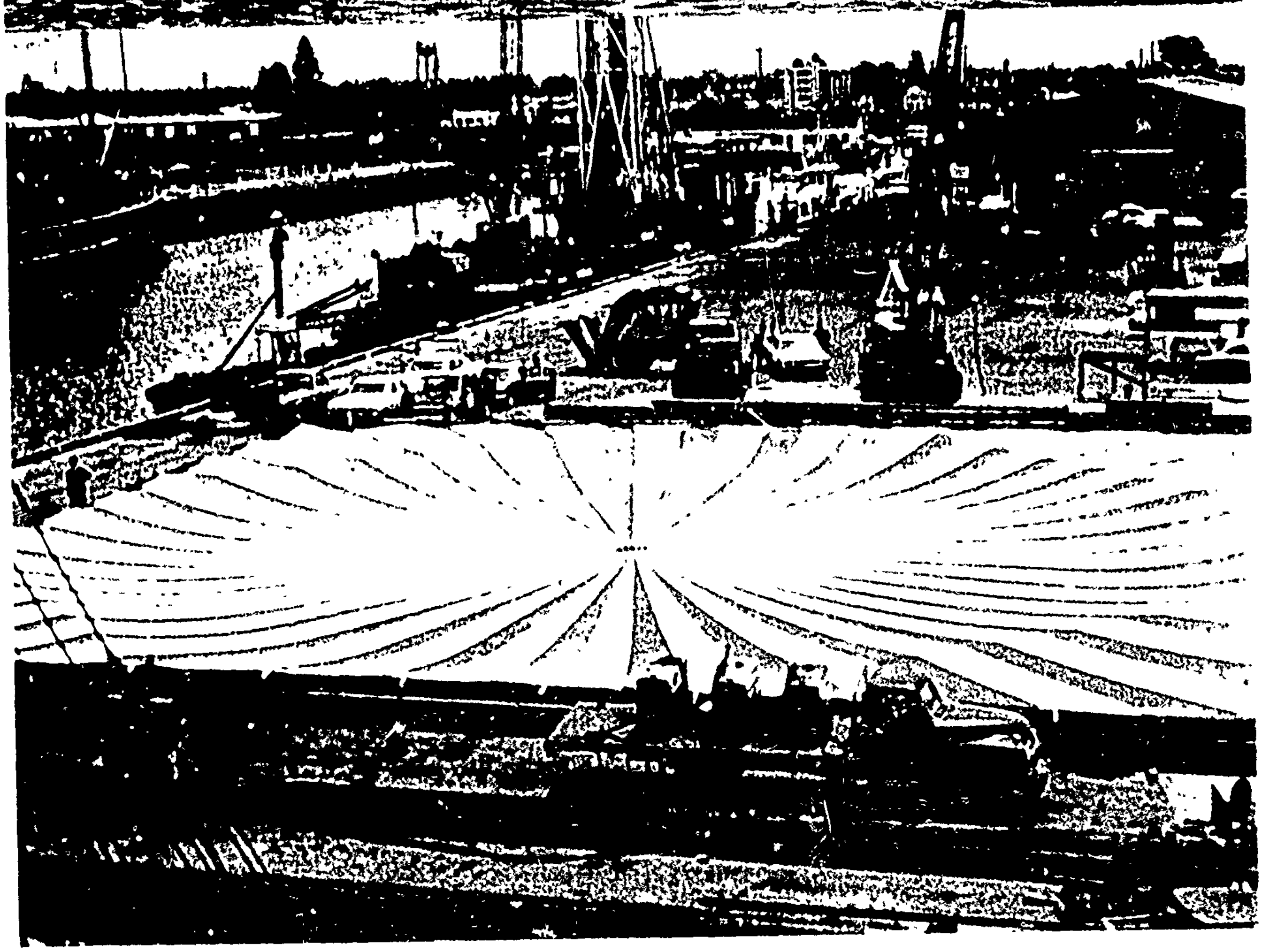
TENT TECHNOLOGY:

In 1969, Richard Headrick was a consultant to Firestone Tire and Rubber Company's Coated Fabrics Division. Immediately following the news announcement of the Santa Barbara blowout, that year, Headrick conferred with Mr. Leonard Firestone and suggested an approach which appeared logical to control the spill. Fabrication soon began on two "tents" - the first, 110 feet square and the second, 65 feet square. The larger was 17 feet high at its pyramidal apex while the smaller was 12 feet. The tents were attached to a welded steel frame consisting of 24" pipe casing, which is the smallest diameter which will float when sealed (schedule 40). The first tents were assembled on a barge and lowered in 235 feet of water to the bottom and positioned over the major seeps. A permanent flotation device was attached along with a 4" hose connection. Crude oil, natural gas and seawater were entrapped by the tent and propelled through the hose line toward the surface by the 17 to 1 expansion of the natural gas. Both tents were manifolded and a floating surface hose line conducted the "product" to the base of the platform 800 feet to the west with enough residual pressure that it could be introduced into separator tank equipment on a low platform deck. Subsequently, improved tents were manufactured, assembled on frames at Port Hueneme and towed to the site. A submarine pipeline was established to carry the product to the platform. Later, additional tents were installed and joined to the manifold system. It is reported that the system is still collecting oil after ten years of operation.

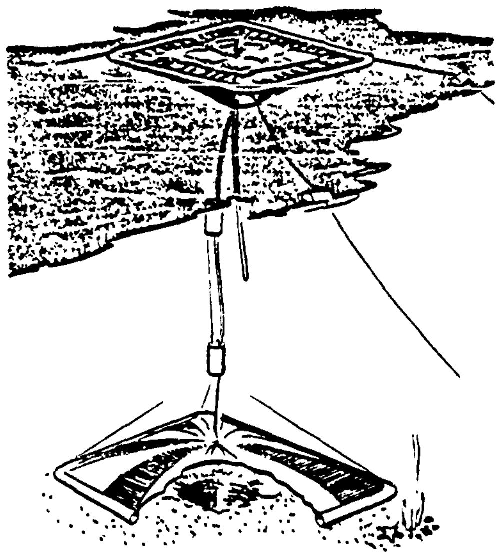


TYPICAL TENT FARM





This technology was reported by the media, particularly television, as having saved the Santa Barbara Channel. It certainly reduced an apparently uncontrollable disaster to a technical accident with remedies. The momentum attained by environmental groups, however, has over-shadowed the technological advances made as a result of the Santa Barbara spill.



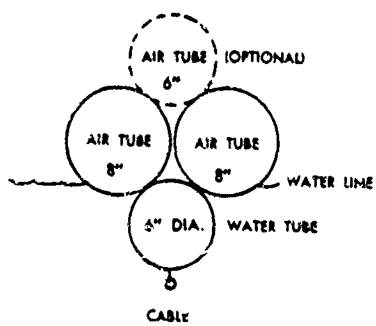
ARCO TENT AND FLOATING TANK CONFIGURATION, PLATFORM HAZEL, SANTA BARBARA CHANNEL

The sudden public awareness and sensitivity to oil pollution caused concern at major oil companies for not only man-made spills, but also natural seeps for which they were sure to be blamed - particularly in the Santa Barbara Channel. Therefore, a small tent (25 feet square) was installed for ARCO off Goleta near "Coal Oil Point", a location of historic man-made and natural seepage. The objective of this project was to cover a poorly sealed wellhead from a previous lease. Again, new technology was generated. The site's distance from Platform Hazel precluded the use of a submarine pipeline. A Firestone square 10,000 gallon embankment tank was modified with suitable attachment points and lashed loosely in a 24 inch pipe casing frame. This tank was equipped with a receiving line connection at bottom center, a displacement line connection nearby to which a weighted open hose was attached allowing water to be displaced back into the ocean while oil was retained in the tank. A standpipe in the center of the tank disposed of natural gas. On the bottom, a small 25 ft. tent was installed on its own frame with its product line going to the bottom of the floating tank. The entire surface assembly was moored from four spring-buoys. The system functioned perfectly until ARCO was able to reseal the wellhead. Collected oil was periodically pumped from the surface bag by a lighter.

Tent technology ultimately requires the state-of-the-art in material, assembly, configuration, rigging and installation. For this limited type of spill, the invention was highly successful. This solution was evaluated as not having a wide market however. It was recently reported, however, that PEMEX has over 60 Gulf installations contributing oil leakage of various quantities and that PEMEX may require correction of these leaks. Perhaps the tent approach has a wider application than originally anticipated, or perhaps the existence of bottom seeps is now more sensitively observed. But regardless of the motivation, to prevent environmental damage from natural or man-made oil pollution, it is logical that its source should be nipped at the bud.

BOOM DESIGN:

If early control of a spill could not be accomplished, then the focus became clean-up of a migrating and dispersing field of surface oil. It was important to produce a boom which would not include ineffectual "skirts" and which would remain stable on the surface with its draft and freeboard remaining relatively constant. This boom should be lightweight and easily transportable. The resulting Headrick development was a remarkably efficient boom consisting of three tubes continuously sealed to each other. Two on the surface were air filled and lightly pressurized. One underneath the center was water filled but not pressurized. The rigging cable was continuously attached along the bottom side of the water tube. The resulting boom was sufficiently stable that crewmen actually walked along it. Since no ballast whatever went with the boom, it was very light. The water-filled chambers were neutrally buoyant, which in fact prevented the boom from broaching under wave crests. With great longitudinal tension on the rigging cable, the water filled chambers act as large ballast preventing the boom from lifting out of a trough. A hard, pontoon-shaped bow was provided for a towing attachment point. Quick-fill was by a small, very high pressure air bottle and an aspirator which multiplied the fill volume. Small volumes of low pressure were easily provided for periods of extended use.



HEADRICK BOOM CROSS-SECTION

BOOM LIMITATIONS:

Now, with a good boom, the question was, how to use it? Dr. Moye Wicks at Shell Pipeline Research in Houston proved conclusively that regardless of the shape of the boom, current running common to it (or across it) will ultimately carry oil under it. The time delay has to do with volume, the thickness and viscosity of the oil and the current velocity. He estimated that oil retention even in calm water was impossible at over about one-half knot. Skirted booms simply do nothing. Any current at all raises the skirt regardless of ballast. Computed ballast requirements in some skirt designs reach millions of pounds.

ANGLE TECHNOLOGY:

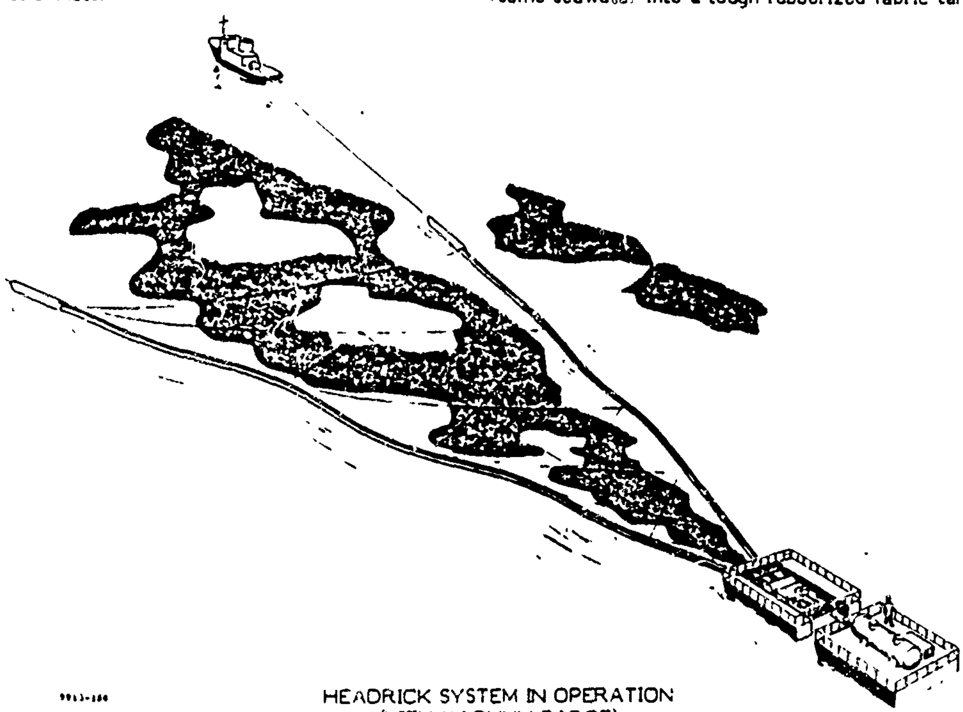
Headrick research at Cal Tech turned up an interesting constant about the bow wakes of ships. The bow wake in saltwater was noted to be 19° 28' on each side of the vessel's track over virtually all practical velocities regardless of hull design or displacement. It was believed that this might be a resultant energy reflection angle relating to the transfer of energy through seawater. A small set of booms was constructed for test. At angles exceeding 40°, ECCOPERL microencapsulation spheres used to accurately simulate oil on water, would eventually underflow the boom as had been shown by Dr. Wicks. At angles less than the precise 38° 56' included angle, however, it was found that the underflow would cease unless crosscurrents resulting from wave energy or towing the boom-harness assembly around a curve were induced. At an included angle of 24°, no underflow existed. The cable harness consisted of progressively reducing straight line "shoe-lace" catenaries which effectively held the boom sides in straight lines. ECCOPERL tests were conducted with perfect results. The Headrick boom simply did not provide a current across the boom of ½ knot even when sweeping at 6 knots.

SEA DRAGON TESTS

It was at this point that Garrett AiResearch was given a Coast Guard-EPA-API contract to develop an oil separating vessel called the "Sea Dragon". This incorporated some advanced Garrett centrifuge technology. It became apparent that no boom existed which could conduct deliberately spilled oil to the Sea Dragon. Headrick proposed a large boom set which incorporated three air tubes on the surface and one water tube underneath. These booms were two hundred feet long and had a harness assembly permitting a 24° open boom angle. In sea tests spilling actual oil, the Coast Guard test files and report indicated that the boom functioned perfectly, allowing no oil to underflow at any towing velocity, but the Sea Dragon vessel did not function well at that time. This was still a historic test in that it was the first time any kind of a boom system had actually swept oil in the open ocean, conducting it to a concentrated location. The inability of the vessel to collect or process the oil at that point did not detract from the boom system's success.

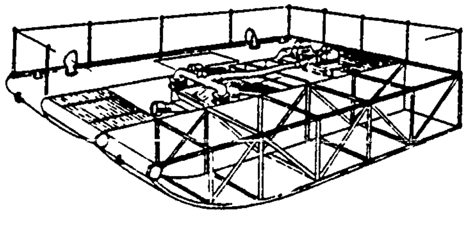
SKIMMER TECHNOLOGY:

With the failure of Sea Dragon, the Headrick research switched to several model concepts of skimming vessels with various performance characteristics. The successful boom and harness design provided ample tests skimming through weathered windrows of actual oil off Coal Oil Point. Finally, a catamaran "sea-sled" hull was designed and tested in model form for high speed towing stability. Later, a full-scale vessel was constructed of marine aluminum. A chamber which could be raised or lowered with a weir entering edge was provided. The water level in the chamber was reduced below sea level by a pumping system discharging the water overboard. An internal chamber was adjustable to skim off the oil falling into the primary chamber and to pump it with some seawater into a tough rubberized fabric tank towed



HEADRICK SYSTEM IN OPERATION
(WITH VACUUM BARGE)

astern. A breather tube and a down line similar to the ARCO tent solution was included.



STRUCTURAL VIEW, HEADRICK SKIMMER

This system was tested extensively in Los Angeles Harbor and off Goleta at Coal Oil Point. A demonstration run was set up with many government agencies and most major oil companies on hand. The objective was to simulate rapid delivery and deployment of a full-scale system behind a ship of opportunity. The system was alerted and dispatched by radio and departed from the Santa Barbara harbor at 28 knots for Coal Oil Point. Arriving minutes later, the floating tank was deployed along with the booms, the tow was picked up by two outboard service boats, and the system was underway collecting actual oil in 8 minutes. Headrick reasoned that rapid surface delivery was essential.

DEMONSTRATED TECHNOLOGY

1. SAN FRANCISCO COLLISION:

In 1971, two Standard tankers collided in the San Francisco Bay. The William F. Hutchinson Company in Wilmington was aware of the Headrick development and had assisted in testing. They were awarded a contract to assist in the bay cleanup and subcontracted the skimmer function to the Headrick group known then as Headrick Industries, Inc. Overnight, the system was transported to Richmond and was put in service the following morning, remaining active nearly continuously for the ensuing 8 days. Most official observers noted that the Headrick system probably cleaned more oil, oil soaked straw and trash of every description than all other equipment combined. An interesting confirmation of the angle technology was that even in thick oil, the oil did not slide along the boom but almost a foot away from it. As a result, the booms were hardly soiled in the San Francisco spill. Following this success, the system was shipped to a petroleum equipment exhibit at Tulsa as the featured exhibit courtesy of the EPA.

2. LAKE MARACAIBO TESTS:

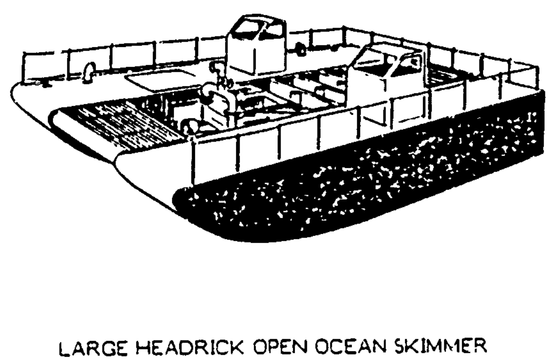
After the Tulsa show, the system was conditionally purchased by a servicing contractor at Lake Maracaibo. Tests were conducted under Headrick supervision with spectacular results. This must be the foulest body of water in the world with so much oil that sometimes sweeping produces clear patches of water that look strange by comparison. The warm water and oxygen support rapid algae growth which in turn causes the oil to biodegrade over an extended period. Political considerations including arbitrary fines for estimated numbers of barrels of oil spilled into the lake made the operation counter-productive in the view of the local oil companies. In this case and in many others, having technology for controlling oil spills had an inverse effect on contingency liability. There was a preference for an "act of God" posture with limited contingency liability. Nationalization of the oil interests followed shortly thereafter and the system was ultimately confiscated. However, the technology had been proven successful even in these heavily polluted waters of Lake Maracaibo.

3. JAPANESE MINISTRY OF TRANSPORTATION AND EFFECT ON FUTURE CONFIGURATION:

An additional system was constructed at the request of the Japanese Ministry of Transportation. Its operation in Japan coincided with a major spill in the Inland Sea. Significant changes were made in skimmer technology by use of vortex skimming which was more efficient in terms of a lower percentage of seawater inclusion in oil transfer.

THE TECHOLOGY CONTINUES TO ADVANCE

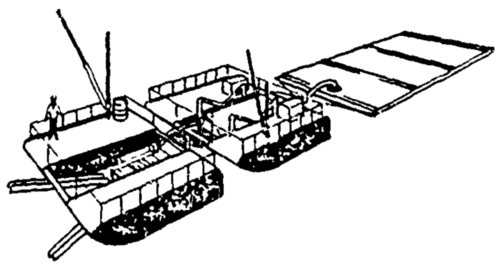
In addition to vortex skimming, it is now proposed to add a vacuum function to the system package. It is also hoped to do a scale-up version of the complete system to provide crew protection, communications, limited mobility (except in the skimming phase) and generally greatly increased capacity for all functions. The smaller 100 ft. boom systems as in the current design would race to the site of the spill and, if there is any current, attach themselves statically to the source, such as a hole in the side of a tanker. Additional units would be put into service to "chase" oil that had passed this position. Meanwhile a larger system could move into place and take over from the source, freeing the smaller, more flexible units for cleanup patrol. All components would be designed to be airborne, probably to fit inside a C-130 (or two C-130's in the case of the larger system).



LARGE HEADRICK OPEN OCEAN SKIMMER

THE CURRENT STATE-OF-THE-ART

Given seaway, these systems can handle any ocean or harbor spill. Restrictions in a harbor are maneuverability of the systems which may be countered by making the catamaran self-powered to operate in a limited area without the boom but with shorter fixed deflector panels set to the same angles. Limitations in the open ocean relate to the nature of the spill and extreme sea states. Bottom blowouts such as the Santa Barbara Channel accident can be swept readily as in the San Francisco Bay collision. A tanker holed out on rocks in a driving gale on a windward shore and breaking up in fifty foot seas is quite another story. A heavy oil slick will have a tendency to be sea limiting with respect to measured sea state. The Headrick systems should nevertheless be seaworthy to state five. The effectiveness of oil collection naturally relates to seas breaking across the booms. The clean-up of most oil spills can be effected by this technology with few exceptions and limitations.



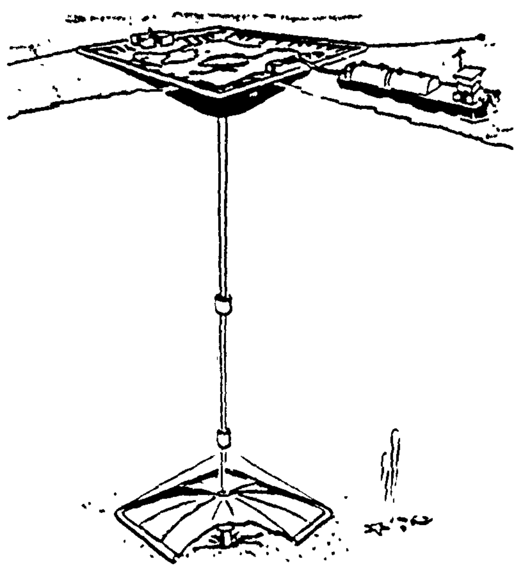
HEADRICK "QUICK RESPONSE" SKIMMER, VACUUM BARGE AND FABRIC TRANSFER TANK

POSSIBLE GLOBAL MARINE PARTICIPATION:

It is proposed that Global Marine may perform a major service, worldwide, to respond to oil spill emergencies by drawing upon their experience in the offshore oil industry. Today, casual spills may exceed millions of gallons. This is attributed primarily to the tremendous increase in tanker capacities. Therefore, oil spill containment systems at a minimum must have similar capacities. Recovering oil from water must include considerable percentages of water which must then be rapidly decanted. Either rapid decanting throughput or storage which exceeds the spill by at least 50% must be available. To respond effectively in this area, Global Marine is studying a completely integrated system capability strategically stored in geographic zones representing immediate high-risk areas. This technology may be incorporated into a master-barge based system in which the barge is the mother vessel, carrying a superskimming system and several smaller quick response systems. Also transported would be high speed towing and service vessels. The barge would be designed to provide full vacuum and decanting capability and would discharge to other barges after decanting, thus reducing the static containment capacity requirement for the barge. These "superbarges" can be semimothballed while retaining quick reaction time. Operating crews consisting of normally off-duty personnel from Global Marine's drilling fleet would move quickly by air to the deployment site. Some light equipment could be air delivered while the barge which is essentially empty at this juncture would be towed by a fast oceangoing tug at perhaps 18 knots. Nearing the scene, light equipment would be deployed and towed ahead at 28 knots to go into service. Locally available tankers and barges would be chartered and conscripted into service as support containers. The use of "Dracones", "whales" or other superlarge fabric tanks is not favored. The reason is the extreme hazard in handling, possibility of snagging in harbor and almost impossible problems of removing cold bunker C from them. Conventional barges are certainly more suitable. Other functions would operate from the barge including a massive firefighting foaming capacity as well as large booms of Headrick design which could surround a floating fire source or platform and deluge it with two feet of foam. (The booms are made of fire-resistant material.)

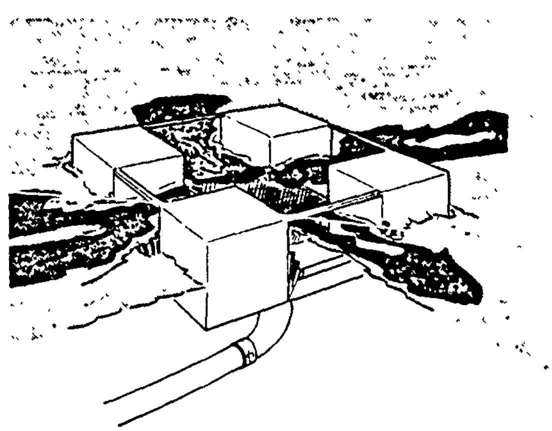
PEMEX TYPE BOTTOM BLOW-OUT PROTECTION:

A very advanced technical approach has been developed by the Headrick team for Global Marine Development Incorporated. This will go directly to the problems involved in the PEMEX blowout. The system does not apply to plugging the well or capping it. What it is designed to accomplish is a system of noncritical total containment and recovery which even might be semipermanent to a similar degree that the tents adjacent to Platform A in the Santa Barbara Channel have been. This approach would not impede slant intercept drilling. Surface fire hazard would virtually be eliminated. Product delivery would be pressure regulated. Comparatively simple and readily transportable components would be used which could be adapted to locally available service vessels and barges in a matter of a few days. The skimming systems previously described could then be dispatched at high



FOR MAJOR SPILLS...HIGH CAPACITY TENT AND OPEN TANK ON SURFACE WITH HIGH SPEED VACUUM BARGE

speed to overtake and recover oil that had moved away with the current and/or wind meanwhile. The nature of this system is highly proprietary and it is security sensitive. With confidential disclosure documentation, Global will brief interested parties on this new approach.



FOR MINOR SPILLS....HEADRICK SMALL FLOATING WEIR SKIMMER FOR HARBOR USE

CONCLUSION:

Global Marine Development Incorporated has a sincere and long-standing interest in providing technology designed to unlock the ocean's secrets, explore and exploit vast invaluable resources under the ocean and at great depth and to protect the ocean environment reckless exploitation. Thus the system of environmental protection may be applied efficiently to the present worldwide petroleum community with technical impact which might ultimately reshape sea law. Global is willing to explore combining of technologies where it can be shown that the Global proprietary approaches will make other systems function better. Global has long believed that the Headrick sweeping technology easily represents the one prime outstanding technical achievement in the entire field of oil spill environmental research and development. Relatively crude empirical attempts in this direction have resulted from the sheer desperation of trying to make stubborn boom systems work. It is most unfortunate that these inventions were at one time widely known and publicized and yet appear to be forgotten or ignored. So important was the "angle" technology that it (the angle) was patented (Patent Number 3,662,891, Edward Headrick, issued May 16, 1972). The unusual optimized boom cross section designed for use with the cable harness making up this system also represents an important techological development (Patent Number 3,567,019, Edward Headrick, March 2, 1971). The combination of these advances along with other skimming and tent technologies outlined in the foregoing are of critical importance to environmental and operational agencies now.

BIOGRAPHY:

Richard T. Headrick of Irvine, California is a retired Lt. Col. in the United States Air Force as well as a pilot in the Royal Canadian Air Force. He flew a total of 96 combat missions and holds the Distinguished Flying Cross, the Bronze Star and 12 Air Medals, in addition to numerous other U.S. decorations and the Distinguished Flying Cross of the Royal Jugoslav Air Force in Exile. He commanded a bombardment squadron and then became Assistant Operations Officer for Fifteenth Air Force in Bari, Italy. He served on General Eisenhower's staff in preparation for the Normandie Invasion which he flew air cover in. At war's end, he held a position in aviation research at Wright Patterson Air Force Base.

After several years in commercial aviation, Headrick became Chief Engineer for Bowser, Incorporated, Defense Division, in Ft. Wayne, Indiana and launched a career of inventions. He is generally credited with the development of Mil F. 8901-A technology for aircraft fuel decontamination and water removal. While with Bowser, he invented the A/E32R-1 Air Transportable Hydrant System which is still in use on Tactical Air Force bases. His next invention was the Navy "Turbocraft-Headrick Air Transportable Fueling System" one of which has been in constant use since 1963 at Pautuxent River NAS. Joining Air Logistics Corporation in Pasadena, California, he invented the A/E32R-14" "Boondocks" air transportable fueling system which was extensively used by all services in Viet Nam in place of conventional but non-existant fixed base hydrant systems. Next in line was the popular "Miniport" system for fueling helicopters in an advanced combat zone in Viet Nam.

Headrick considers his most important invention to be the surge-resisting "bladder tank" which permits fuel to be transported in cargo aircraft. This changed overnight all concepts of moving fuel in a theather of operations. Seven C-130's eliminated fuel tank truck convoys which has been highly vulnerable to Viet Cong attack. This invention made possible the aborted hostage rescue attempt in Iran which was not related in any way to the tank technology.

As an inventing team, Richard and Edward Headrick, his brother, have many joint inventions but digress sharply in their favority areas of technical exploration. Edward invented the Hula Hoop and Super Ball, as well as the present form of the Frisbee and was responsible for their history-making market program at Wham-O Manufacturing Company. The two brothers worked together in the field of oil spill technology. Richard created the tents referred to in the body of this paper, which are credited with totally controlling the Platform A accident in the Santa Barbara Channel in 1969. Edward was the inventor of record for the boom and skimmin systems. Both worked long hour testing and perfecting this technology.

Many inventions later, Richard Headrick was invited by California Institute of Technology and Global Marine Development Incorporated to become a consultant in the area of marine biomass propogation in the ocean to produce methane from the fantastically fast growing Giant California Brown Leaf Kelp. The contract is from the Department of Energy and involves the American Gas Association, General Electric and Cal Tech (which was founded by a relative, Amos Throop and was originally called Throop Technical College. The middle initial "T" is for Richard "Throop" Headrick).

This consulting relationship led to a reexamination for the oil spill technology invented by the Headrick brothers, Edward and Richard, with a license to Global Marine to evaluate possible entry into a worldwide operational capability in the environmental sciences.

APPENDIX:

1. The first color page is an aerial photograph of the 1971 oil spill in the San Francisco Bay caused by the collision of two Chevron Tankers. This is "the morning after". This tanker was nearly cut in half. The other tanker is at the Richmond docks just off the top of the picture. The small white yacht in the foreground is the Coast Guard Spill Command Ship. No oil recovery has been attempted but the Coast Guard is scattering straw.

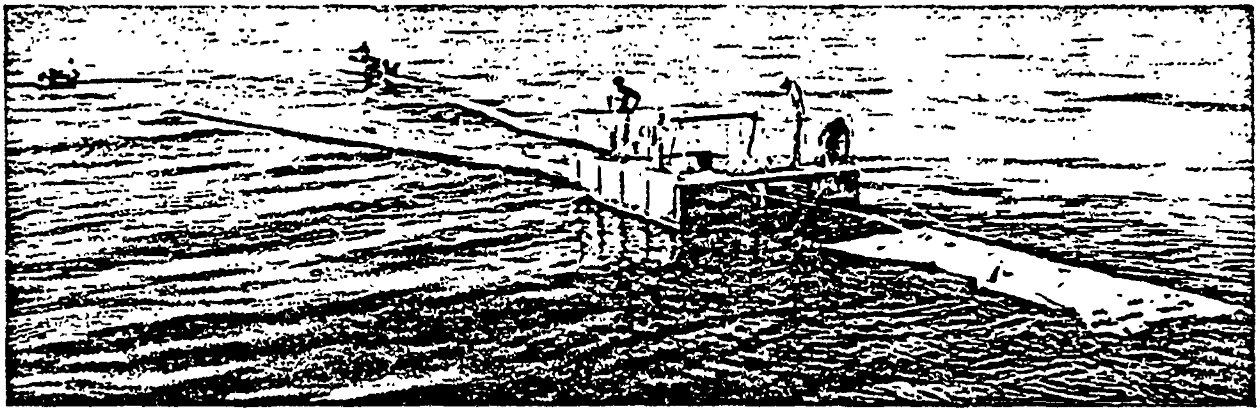
2. 2nd Color Page... The Headrick (Firestone) 110' tents (bottom) assembled to pipe frame on dock at Port Hueneme. (Top) Floating in water to be towed to vicinity of Platform A (1969).

3. Full Page Story... "Prototype System..." In Ocean Industry, January, 1971.

4. Montage of Spill Stories in Press.

Note: The following pages illustrate some of the fuel and fabric related inventions of Richard T. Headrick, licensed to Air Logistics Corporation in Pasadena, California and used extensively in Vietnam. Of particular interest is the C-130 tanker conversion set which provided the fuel logistics for the aborted Iran rescue attempt.

These are included to document the Headrick technical background which contributed directly to their interest in using fabric systems for Ocean Environmental Protection. (This is also for the benefit of this workshop since the Air-Log briefing is back-to-back in the opposite workshop).



COMPLETE OIL SPILL RECOVERY SYSTEM.

Prototype system contains and removes oil from water

HEADRICK INDUSTRIES, INC., has tested a complete open-ocean oil recovery system near Coal Oil Point, Calif., a natural oil seepage point in the Santa Barbara Channel. The system includes booms, towing harness, recovery and transport vessel and fabric tank for collection, separation and transport of floating oil.

An angle towing harness assembly was used which retains the boom legs in straight lines that converge into the oil recovery separation apparatus at the apex. The system has longitudinal tubes filled with sea water and supported by air (OCEAN INDUSTRY, June 1970, Pages 51-56).

Testing the system

A catamaran barge towed by a 31-ft sportfisher carried all apparatus required for the first-phase tactical deployment of the system. The system was delivered at a measured 26 knots to location. Two small outboard vessels also accompanied the deployment. On location, the outboards picked up tow lines from the right and left boom segments. Moving forward slowly, the entire apparatus was launched.

Two high-pressure air bottles were then discharged into the air tubes to inflate the boom legs. The air tubes were 8 in. in diameter, and the boom legs were 100 ft long. Air-fill time was less than 3 seconds. At the same time, a high-speed pump on the catamaran, normally used for oil transfer, was valved to fill the water tubes. This operation required slightly less than 30 seconds. Simultaneously, technicians on the barge pushed the 3,000-gallon-capacity rubberized storage tank off the stern of the vessel with hoses attached to the oil transfer system.

From the "go" signal to the point when the system was in full operation and capable of collecting and transporting oil was approximately 8 minutes.

SURFACE OIL is directed through oil separator system and pumped into fabric tank.

The technique for oil separation does not incorporate centrifuges but encourages flow of a controllable and limited surface depth of water into an unagitated gravity separator. The surface of the liquid in the separator is then precisely skimmed. The skimmed oil is transferred to the oil storage tank which becomes an additional gravity separator which has a deep water balance line below its center to allow displaced water to flow back into the ocean.

The operating system can accommodate varying slick and sea state conditions, as well as varying types of oil. Maximum oil transfer capacity is 800 to 1,500 gallons per minute, assuming the system is located directly on a massive "crowning" slick. Conversely, the system skims rainbows off the surface.

A second backup system with substantially larger boom cross sections and lengths is planned, as well as a catamaran vessel possibly 40 ft long with crew accommodations. Floating storage tanks of capacities up to 100,000 gallons will be used.

Headrick has been nominated by Rep. H. Allen Smith (R-Calif.) for a government award under Public Law 91-224. The company currently is working with Firestone Coated Fabrics to develop a range of floating oil storage and transport tanks that will permit gravity separation and provide a completely seaworthy and towable fabric tank. ■

Reprinted from OCEAN INDUSTRY January, 1971
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'2* Los Angeles Times   Sun., June 10, 1979—Part I 3

'79 May Be Worst Year for Oil Spills

204,000 Tons Lost by Tankers in Only 5 Months Nearly Equals Total for '77

BY WILLIAM C. REMPEL
Times Staff Writer

The Greek tanker Andros Patria, fighting heavy seas off the northwest coast of Spain, neared the end of its long voyage to Rotterdam from the Middle East in the closing moments of 1978.

But the New Year's Eve celebration on board was preempted by disaster—pounding waves cracked the ship's hull and a short circuit touched off an explosion that left the giant tanker dead in the water.

In the early hours of 1979, 34 people—including the ship's captain and his wife and son—abandoned the burning tanker, climbing into life boats that capsized in the storm. All died.

An estimated 68,000 tons of Iranian crude oil poured into the sea, inaugurating what could become the history worst oil pollution year in the world tanker fleet.

Today, only five months into 1979, tanker accidents have spilled 204,000 tons of oil—about 62 million gallons. This matches the amount of oil spilled during the entire year in 1976 and is just shy of the 1977 annual total of 213,000 tons, according to figures of the Tanker Advisory Center in New York.

Only 1978 with its record 260,000 tons of spilled oil maintains a significant lead in the dubious race for pollution supremacy.

And last year's total is largely the spill—the Amoco Cadiz that dumped single

With nearly seven months remaining in 1979, including the frequently stormy period from October through December, this year's fast start on spill incidents has tanker experts fearful this could still be the biggest pollution year ever.

It also figures to be among the most deadly—128 persons have died or disappeared in tanker accidents so far this year. Only 1978 with 226 killed and 1976 with 148 deaths exceed this five-month total, according to the Tanker Advisory Center's statistics.

Weather has been a major contributor to this year's burst of tanker losses.

The Cypriot-flag tanker Master Michael, like the Andros Patria a day earlier, caught fire during a January storm in the Caribbean. A cargo of 5,600 tons of diesel fuel oil went down along with 31 crew members.

Severe weather also was blamed in part for the loss of the British tanker Kurdistan off the coast of Nova Scotia in March. The tanker, laden with fuel oil, split in half after hitting an iceberg during the storm.

A military helicopter braved raging winds and seas to pluck all 41 crew members to safety. Much of the cargo also was salvaged, but 13,337 tons went into the sea.

At about the same time the Liberian-flag Sea Valiant enroute to Philadelphia encountered an Atlantic storm that ruptured its hull, spilling 1,700 tons of oil.

Please Turn to Page 30, Col. 1

30 Part I—Sun., June 10, 1979   Los Angeles Times *

'79 May Be Worst Year for Oil Spills

Continued from Third Page

By far the most spectacular disaster so far this year was the explosion of the French tanker Betelgeuse in January while discharging crude oil in Bantry Bay, Ireland. The ... alongside the Gulf Oil terminal took 47 lives, the most ... single tanker disaster in history.

... 40,000 tons of oil spilled into Bantry Bay, ... remains closed, with more than 250 ... there in storage tanks. ... cause of the explosion ... they believe the 120,... under stress...

Another 2,500 tons was spilled into the waters of the Suez Canal when the Liberian-flag Skyron II bounced off the canal bank after punching a hole in a cargo tank.

Some of the most serious damage from oil spills resulted from some of the smaller spills. For example:

—Only 540 tons of oil was spilled after the collision of two Japanese tankers, the Miya Maru 8 and the Daikoku Maru 18, in Japan's Inland Sea in March. However, extensive damage was reported to nearby oyster beds and to fish and seaweed farming facilities.

—In Denmark about 400 tons of heavy fuel oil spilled from the Swedish tanker Thuntank 3 in January, killing an estimated 30,000 birds (mostly Eider ducks), according to the Oil Spill Intelligence Report.

And in one freak accident ... blew up in Nederland, Tex. ... ing during crude oil disch... seriously injured. ...

... Liberian-flag Seatiger ... struck by lightning ... killed and ... were ...

... The Ministry of Interior ... Turku Archipelago ... The beaches at ... the grounding of ... the ship's bow ... into the sea.

Oil Well Spill May Hit U.S. Coast

CAMBRIDGE, Mass (AP) — The uncontrolled gush of oil from a ruptured Mexican well may become the biggest spill in history and could threaten the coasts of Texas and Louisiana, petroleum specialists here said Monday

Richard Golob, director of the Center for Short-Lived Phenomena, said that about 1.2 million gallons a day are escaping from the Pemex well in the Gulf of Mexico off the Yucatan Peninsula. The exploratory offshore well blew out on June 3

"If the oil continues to escape at the current rate and if the well is not capped before the estimated time of control, this will become the biggest spill in history," Golob said

Golob said the prevailing currents will eventually carry the oil along the Mexican coast toward Texas and Louisiana. Unless there are tropical storms, it will probably take the oil 25 days to drift 700 miles to Texas

"By then it will have weathered considerably into tar balls," Golob said.

However, the threat to American beaches is worse if the flow of the oil is speeded by a hurricane.

"May and June are the start of the hurricane season," Golob said "This potential could bring to the U.S. coast a significant amount of oil."

Mexican officials have said it will take them between 100 and 180 days to cap the well, which is broken under water

By that time, Golob said, more than 100 million gallons of oil will have escaped. Until now, the biggest oil spill in history was the wreck of the Amoco Cadiz, a Liberian tanker that ran aground off France last year and spilled 68 million gallons of crude oil

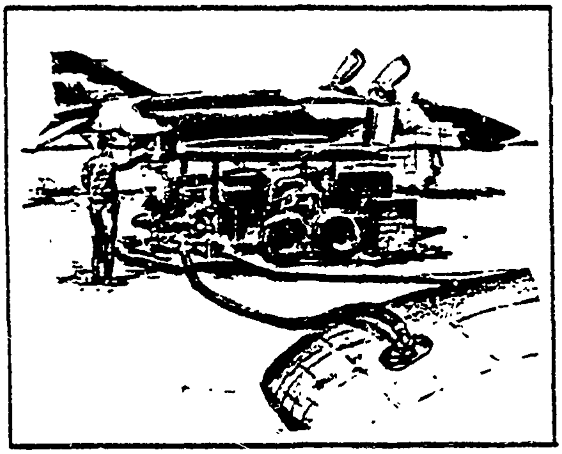
The broken well, called Ixtoc 1, is about 50 miles off Ciudad del Carmen, where Pemex has drilled 11 other exploratory wells without problems

So far, a slick estimated at 10 miles wide and 100 miles long stretches westerly away from the oil well, Golob said.

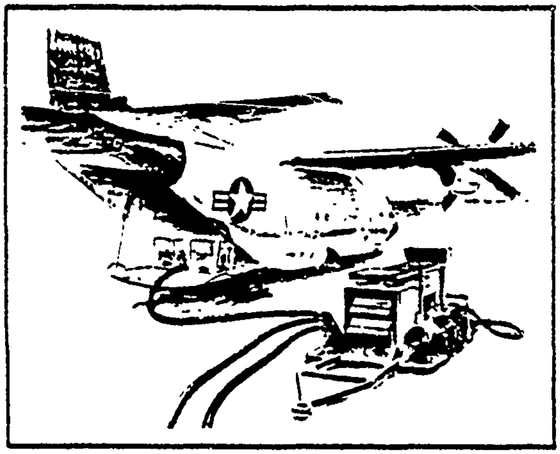
He said the slick has already reached areas where shrimp boats are fishing and threatens other important shrimping grounds

The Center for Short-Lived Phenomena provides information to scientists about natural and man-made changes in the environment and publishes a news letter on oil spills

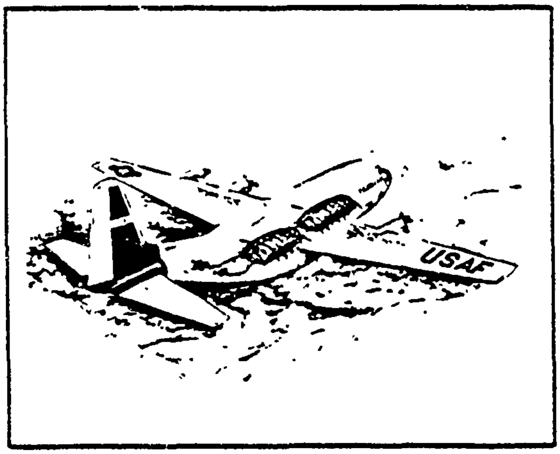
RICHARD HEADRICK INVENTIONS
AIR LOGISTICS CORPORATION



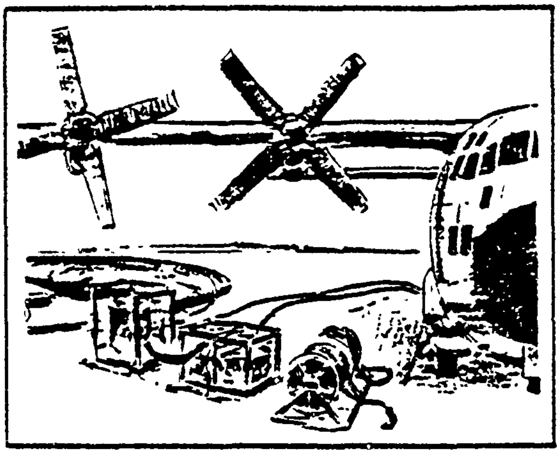
1 AIR-LOG "BOONDOCKS" A/E32R-14 AIR FORCE BARE-BASE FUELING SYSTEM SERVICES TACTICAL FIGHTERS.



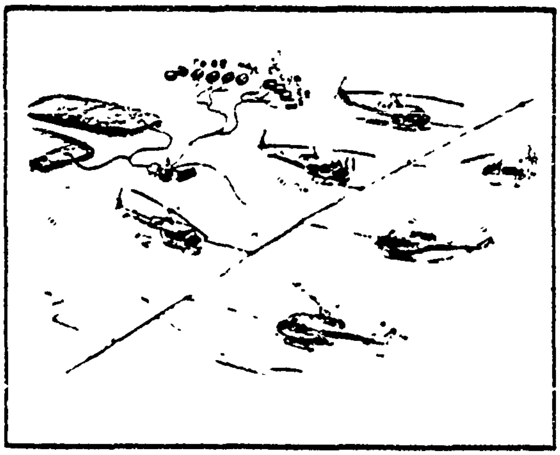
2 AIR-LOG "BOONDOCKS" SYSTEM LOADS C-130 TANKER FOR AERIAL FUEL DELIVERY TO REMOTE AREA.



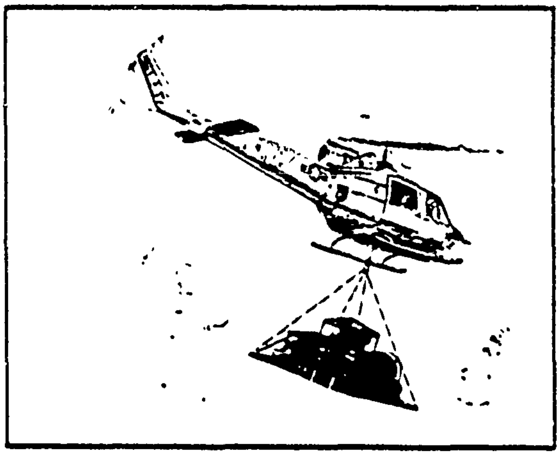
3 AIR-LOG AERIAL FUEL DELIVERY SYSTEM 6000 GAL. TANKER KIT FOR C-130, C-141, C-5A



4 C-130 OFF-LOADS INTO AIR-LOG INTERMEDIATE POL SUPPLY POINT

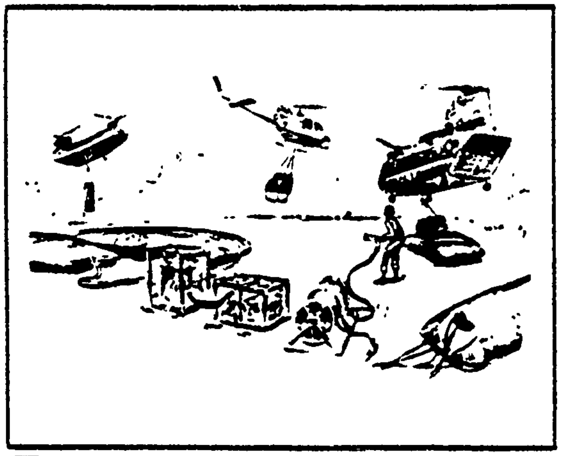


5 AIR-LOG INTERMEDIATE POL SUPPLY POINT SERVICING 12 HUEYS.

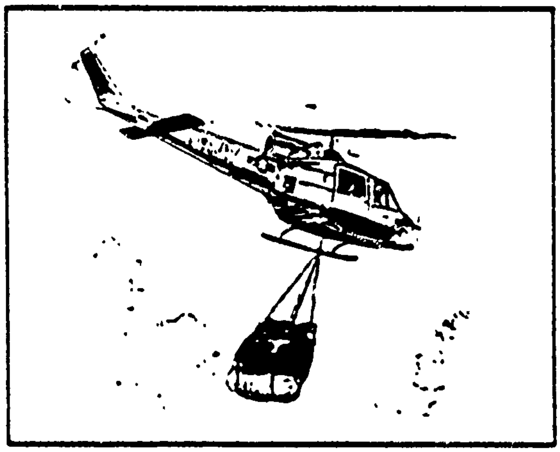


6 HUEY DELIVERS AIR-LOG REMOTE AREA FUELING TERMINAL (RAFT).

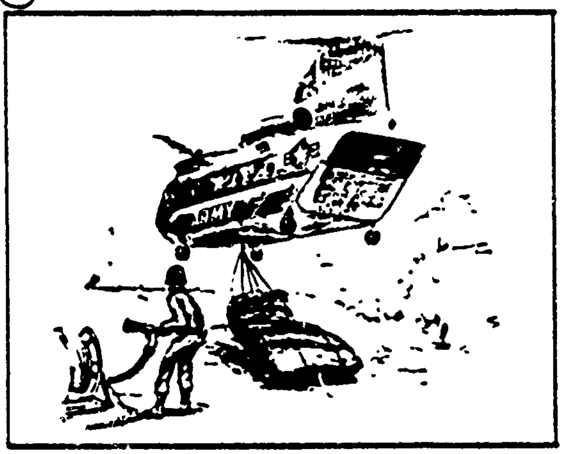
RICHARD HEADRICK INVENTIONS
AIR LOGISTICS CORPORATION



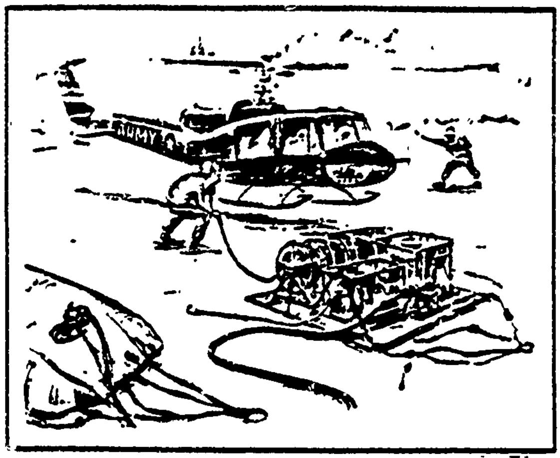
7 AIR-LOG INTERMEDIATE POL SUPPLY POINT FILLS AIR-LOG 500 OR 2000 GAL. TANKS.



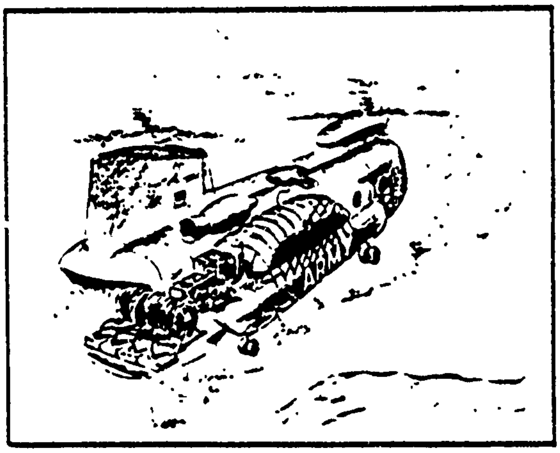
8 HUEY CARRIES 500 GALLON SLING TANK.



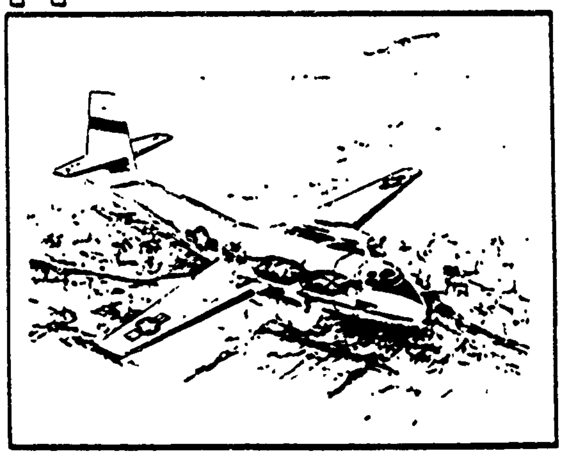
9 CHINOOK DEPOSITS 2000 GALLON SLING TANK AT STAGE FIELD RAFT.



10 AIR-LOG MINIPORT HELIPORTABLE "RAFT" FUELS FOUR HUEYS.

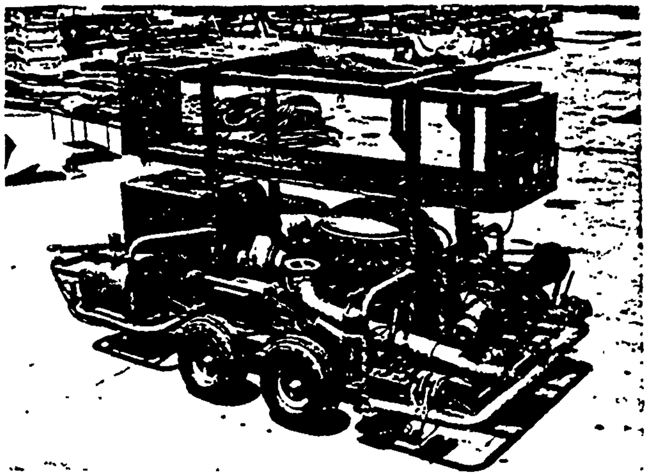


11 CHINOOK "INSTANT" TANKERS — "FLYING COW."

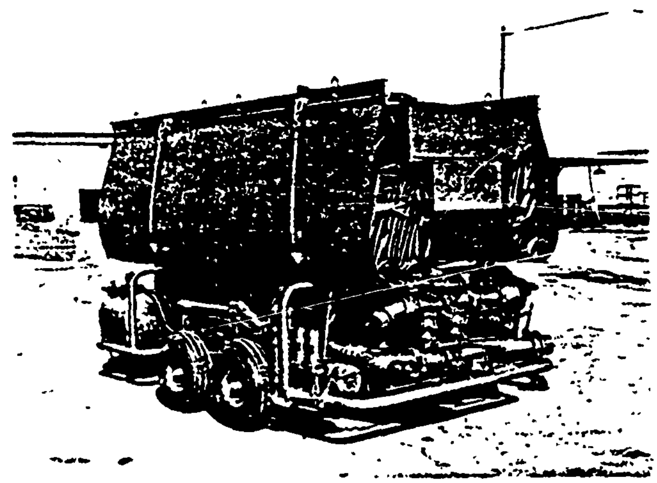


12 CARIBOU TRANSPORTS TWO 500 GAL. TANKS.

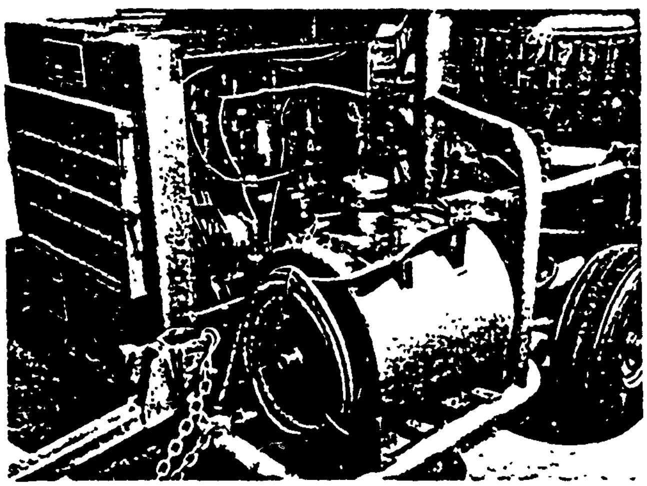
RICHARD HEADRICK INVENTIONS
AIR LOGISTICS CORPORATION



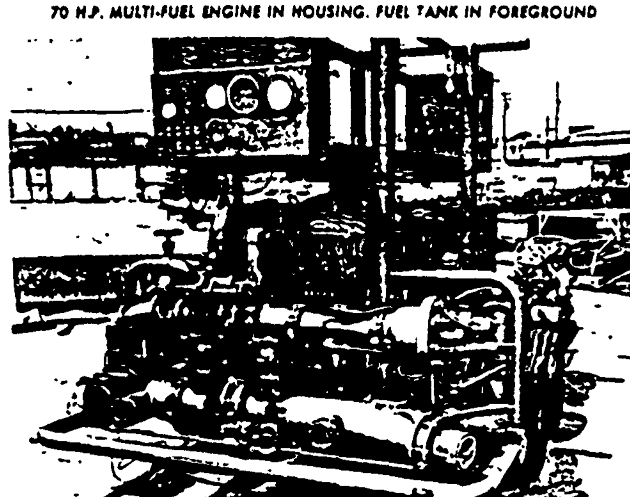
BOONDOCKS PUMPER TRAILER, WHEELS EXTENDED, SUPERSTRUCTURE IN PLACE



COMPLETE BOONDOCKS SYSTEM READY FOR SHIPMENT, 10,000 POUNDS



70 H.P. MULTI-FUEL ENGINE IN HOUSING, FUEL TANK IN FOREGROUND



OPERATING FACE OF BOONDOCKS SYSTEM, INSTRUMENTS, CONTROLS, METER, VALVE HANDLES

THE BOONDOCKS SYSTEM DESCRIPTION . . . GENERAL

The Air-Log Boondocks Air-Transportable Fueling System is a modular, mobile high flow, high storage capacity "bare base" POL system. This system supersedes the Air Force A/E32R-1 and is designated the A/E-32R-14. Reference to the Inclusion List Chart will indicate that a module consists of one vehicle and two 50,000 gallon lightweight ground storage tanks along with hose, valves, adapters, fittings, nozzles etc. The Air Force "Hydrant System" consists of three modules. Each component is designed to be stowed on the vehicle module which also contains the pumping and filtration circuitry.

The weight of the module with all its accessories is approximately 10,000 pounds its overall size permits loading three modules in a C-130 aircraft. The vehicle is 156.0 inches long, 88.0 inches wide and 86.0 inches high with wheels retracted. In normal towing position, the overall height is 93.5 inches. A low towing position for maneuvering in the aircraft reduces height to 91.0 inches. A high towing position for ramp clearance increases height to 102.0 inches. The servicing silhouette with superstructure removed is 72 inches high. Estimated erection time is approximately forty-five minutes. The system has its own hoist to lower tanks or lift them in place in their storage harness. Each module may be operated safely by two men.

CHASSIS

Components of the vehicle are assembled upon a welded tubular steel chassis with retractable 4-wheel tandem undercarriage. Each wheel is independently suspended by its own axle and leaf spring assembly. Two hand pumps are used to raise the vehicle. Normally when stowed in an aircraft the undercarriage is retracted resting the chassis on the floor of the aircraft. In this position the vehicle also becomes a sled for movement over snow.

A superstructure is removable from the top of the vehicle. This supports two slings carrying one 50,000 gallon tank each. Its center portion stows the hose for the system. The hoist assembly may be readily moved to the right or left pivot base and attached to the tanks which may then be cranked up into their locked position.

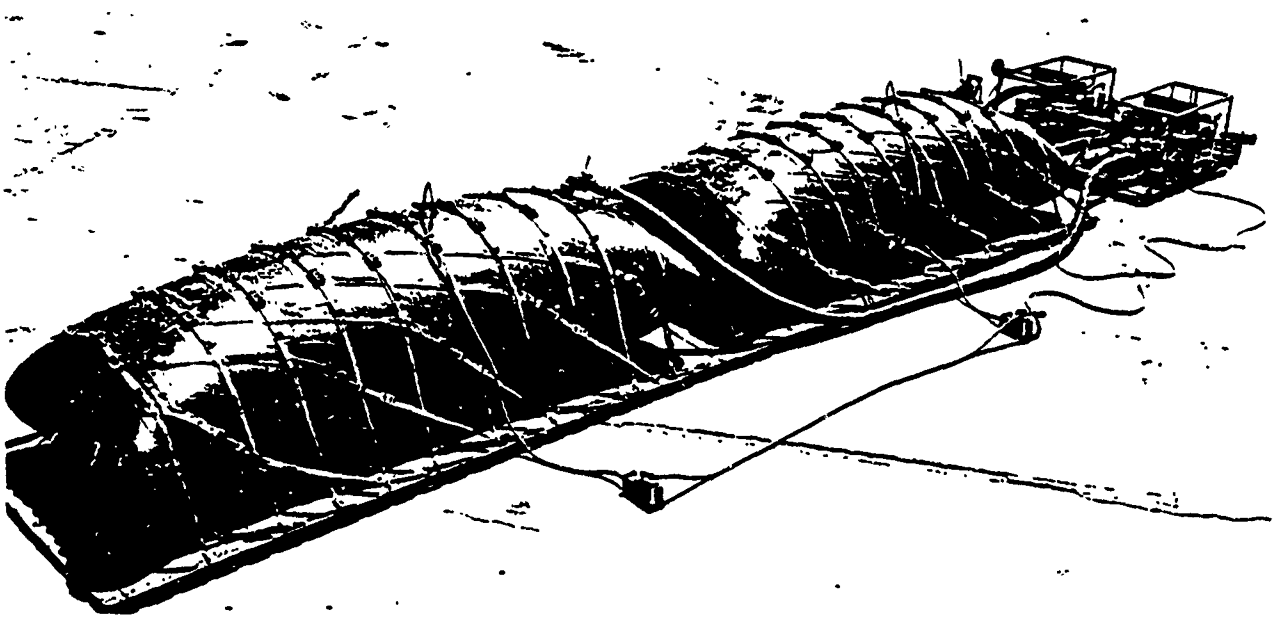
TANK GROUP

Two 50,000 gallon lightweight storage tanks made of polyurethane are provided. These are connected to the vehicle by non-collapsible suction hose through fuel-defuel valves mounted on each tank. The valve opens up under suction to permit off-loading the tank. To prevent overfill, a lanyard attached to a ring on the bottom of the tank triggers a pilot mechanism when the rated fill condition is reached closing the valve. Each of the tanks is rolled up and stowed inside a folded aluminum sleeve the top edges of which are channel and are bolted together. Pins lock the channels to the superstructure and cargo straps secure the load to the side of the frame uprights.

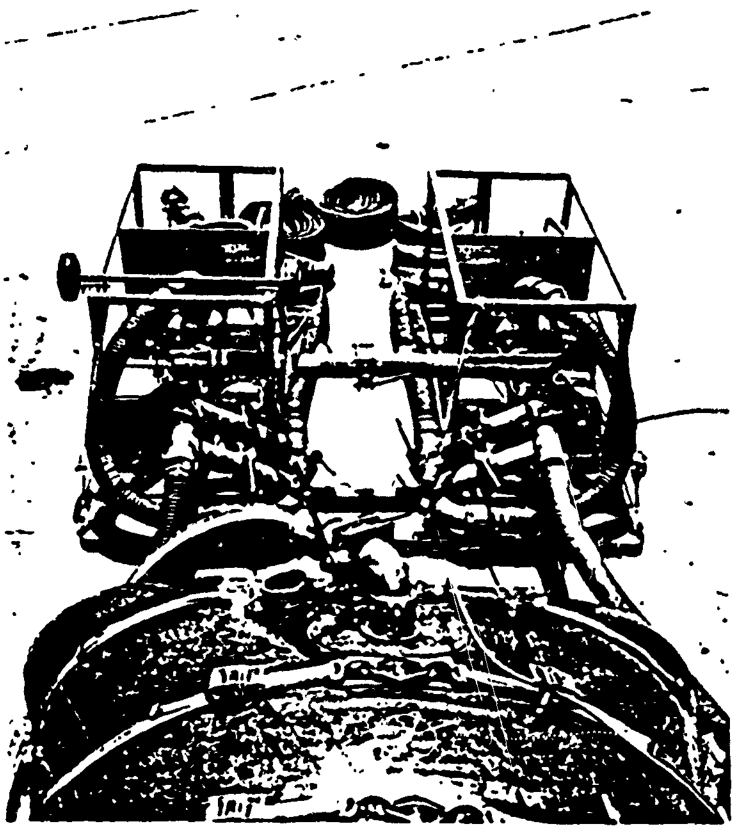
LIQUID CIRCUITRY

Fuel enters the vehicle through a "Y" manifold from two 4" diameter hoses to one 6" diameter pipe past fuel-defuel valving into a 40 mesh line strainer and then into a self-priming centrifugal pump. The pump is driven by a 70 horsepower, three cylinder, two cycle, multi-fuel engine which is capable of operating on most fuels pumped through the system. Provision is also made to draw fuel from a secondary source such as a 55 gal. drum.

From the pump the fuel passes into the filter separator which incorporates thirty MIL-F-8901A interchangeable Department of Defense coalescer elements which are surrounded by a segregator canister constructed of Teflon coated screen



6000 GAL. KIT EXACTLY AS INSTALLED ON C-130 TWO PALLETS ARE 20 FEET LONG BY 108 INCHES WIDE TO FIT 463L RAIL SYSTEM. NOTE DIAGONAL LONGITUDINAL STRAPS WHICH WRAP AROUND FRONT OF THREE-PLY TANK. STRAPS HAVE THREE SECTIONS: LOWER, FIXED LENGTH, MIDDLE, VULCANIZED TO TANK; UPPER, ADJUSTABLE. LATERAL STRAPS ARE ALL ADJUSTABLE AND ATTACH TO DOUBLE DELTA RINGS AT TANK CENTER-LINE. VAPOR ELIMINATOR SYSTEM IN FOREGROUND TOTAL INSTALLATION WITHSTANDS 8 "G" SUSTAINED (OR STATIC) FORWARD CRASH LOAD.



IN FOREGROUND, TANK VALVE, HOSES TO PUMP ENGINE PALLET WHICH IS ON TAIL RAMP OF C 130 NOTE FUEL-DEFUEL VALVING AND CROSS FEED ALL APPARATUS IS WITHIN ENVELOPE LIMITS OF 463L 88" X 108" PALLET INTERCONNECT HOSE FROM AIRCRAFT FUEL SYSTEM AND TWO METERS NOT SHOWN

THE AIR-LOG 3000 GAL. AIRBORNE FABRITANK IS THE LARGEST TANK PRESENTLY RECOMMENDED FOR USE IN AERIAL BULK FUEL DELIVERY DUE TO FLOOR LOADING AND HIGH G RETENTION. THEREFORE, TANKER CONVERSION KITS FOR LARGER TRANSPORT AIRCRAFT ARE MADE UP OF MULTIPLES OF THE SAME COMPONENTS. THESE SAME TANKS MAY BE USED FOR FERRY RANGE EXTENSION. SPECIFIC APPLICATION OF ALL AIR-LOG COMPONENTS FOR THIS FUNCTION IS COVERED IN SPECIFICATION DATA SHEET V ENTITLED "AIR-LOG ANTI-SURGE HIGH G FERRY RANGE EXTENSION SYSTEMS."

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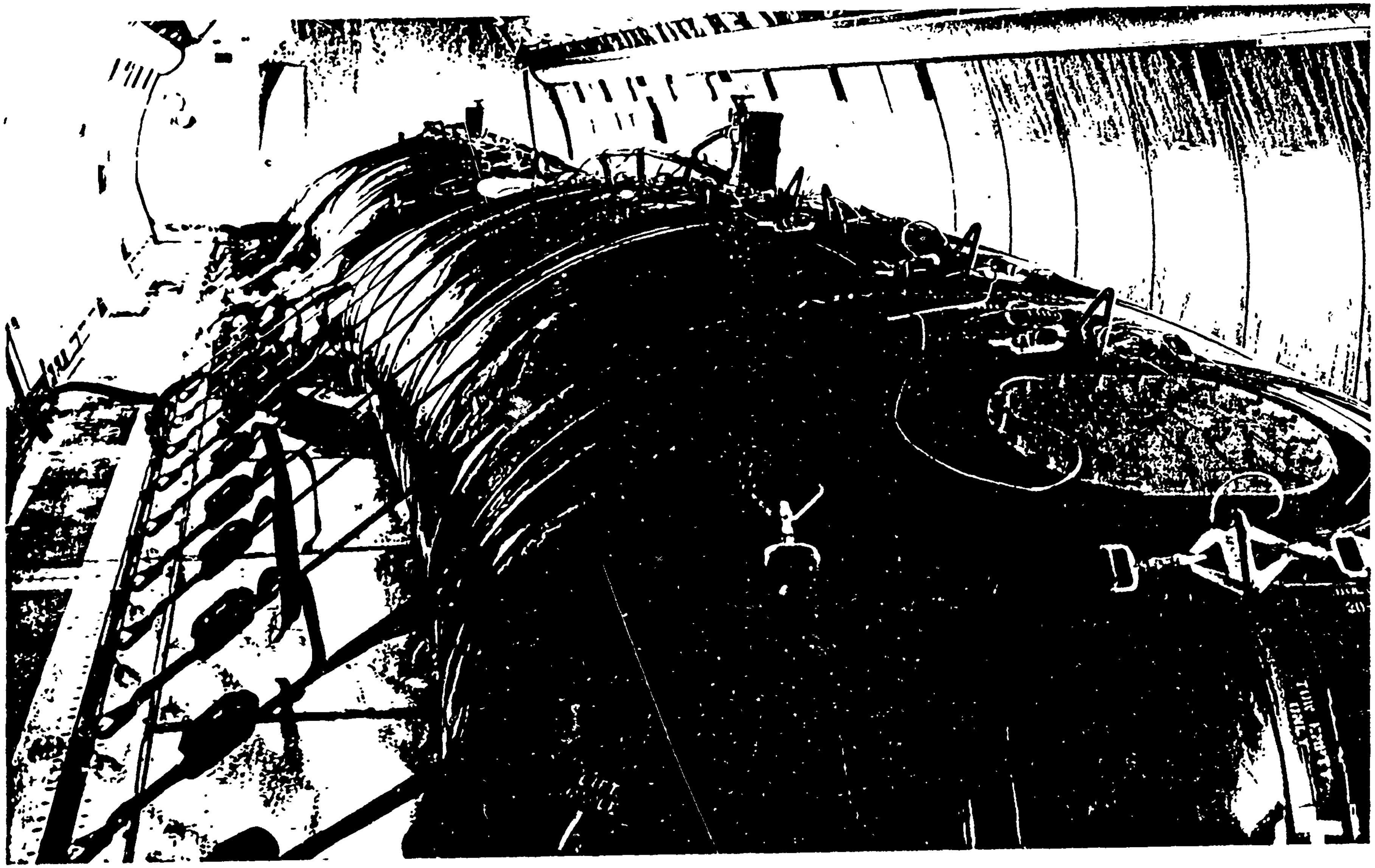

TWO AIR-LOG 2000 GAL. TANKS IN NORTH-SOUTH POLAR FLIGHT
BOEING 707-320 C

A I R   L O G I S T I C S   C O R P O R A T I O N

AIRCRAFT AS A SOURCE OF AIR POLLUTION

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Presented at the INDUSTRY-MILITARY ENERGY SYMPOSIUM

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The results and conclusions of this paper are those of the author's and do not necessarily represent those of the Air Force or other government agencies

AIRCRAFT AS A SOURCE OF AIR POLLUTION

Aircraft are an example of a source of air pollution for which the need for federal regulations can be questioned. While the American public has repeatedly expressed the desire for air quality which poses a low risk to human health and welfare, recent energy supply difficulties and domestic economic problems are strong competition for less immediate air quality considerations. The logical question is therefore, "How necessary and effective are federal regulations for many air pollution sources?" There are no simple answers to such a broad question. Instead, one must focus on individual source categories such as aircraft without losing sight of overall clean air objectives.

The federal Clean Air Act, Section 231, directs the Environmental Protection Agency (EPA) Administrator to issue emission standards for:

> "...Aircraft engines which in his judgement causes or contributes to, air pollution which may reasonably be anticipated to endanger public health or welfare."

Given that strong congressional mandate, EPA first issued regulations for civil aircraft engine emissions in 1973. Numerous revisions have since occurred and are currently under consideration. Critics suggest these regulations are overly complex and too stringent. Detailed air quality studies since 1973 have not reaffirmed any danger to public health or welfare directly attributable to aircraft. Proponents argue that ambient air pollution standards for pollutants such as oxidants are frequently violated and cannot be met unless the best available technology is applied to many sources including those the size of airports. Further discussion of these issues will hopefully promote a more widespread understanding of the basis for aircraft engine emission standards.

AIRCRAFT IN PERSPECTIVE

Emissions from aircraft are a small part of all sources when considered on a national scale. As illustrated in Figure 1, they are about 1 percent for hydrocarbons (HC), oxides of nitrogen (NO_x), and carbon monoxide (CO).[(1)] Particulate matter (PM) and oxides of sulfur (SO_x) are even less. Small general aviation type aircraft are the least important of the three aircraft categories shown and have recently been exempted from all aircraft engine emission standards.[(2)] Commercial aircraft have lower HC but higher NO_x emissions than military aircraft due to a greater proportion of larger and newer engines.

Emissions on regional and local scales are also shown in Figure 1 since identifiable health and welfare effects from air pollution generally occur on these scales. Aircraft contribute approximately 3 percent of all emissions in a 10 county area within a 12 mile distance from the Atlanta, Ga. airport.[(3)] This contribution could increase, however, to about 6 to 10 percent by 1990 as flight activity increases and stringent air pollution controls are applied to other sources. Aircraft related evaporative hydrocarbon fuel storage and transfer emissions may increase four fold in the future due to additional fuel usage. A switch to alternative fuels with lower vapor pressures would lower this projected increase.

Aircraft are the dominant source category within the Atlanta airport boundary as shown in Figure 1. Proposed control strategies have generally focused on aircraft engine emission reductions rather than other airport sources. Emissions data like this may not be representative of air quality effects, however. Aircraft emissions distributed throughout much of the airport and are subject to considerable atmospheric dilution. In contrast, emissions from automobile

NATIONAL SCALE*

SOURCE	HC	NO_x	CO	PM	SO_x
ALL AIRCRAFT (%)	1.2	0.6	0.6	0.3	.08
-COMMERCIAL (%)	0.3	0.4	0.2	-	.03
-MILITARY (%)	0.7	0.2	0.2	0.3	.05
-GENERAL AVIATION (%)	0.2	-	0.2	-	-
ALL SOURCES (1000 Tons/Yr)	30,000	22,000	116,000	36,000	33,000

REGIONAL SCALE**

ATLANTA REGION OF 10 COUNTIES

	HC		NO_x		CO	
SOURCE	1973	1990	1973	1990	1973	1990
AIRCRAFT (%)	3.2	6.2	3.1	7.2	2.4	10.3
FUEL LOSS (%)	0.8	4.0	-	-	-	-
ATLANTA REGION (1000 Tons/Yr)	89	88	75	92	300	156

AIRPORT BOUNDARY**

ATLANTA AIRPORT

SOURCE	HC	NO_x	CO
AIRCRAFT (%)	69	78	58
FUEL LOSS (%)	11	-	-
TRAFFIC, MISC (%)	20	22	42
TOTAL AIRPORT (1000 Tons/Yr)	3.9	2.9	9.5

* SOURCE: 1976 NEDS DATA, EPA-450/4-79-019 (1979)

** SOURCE: EPA-450/3-75-052 (1975)

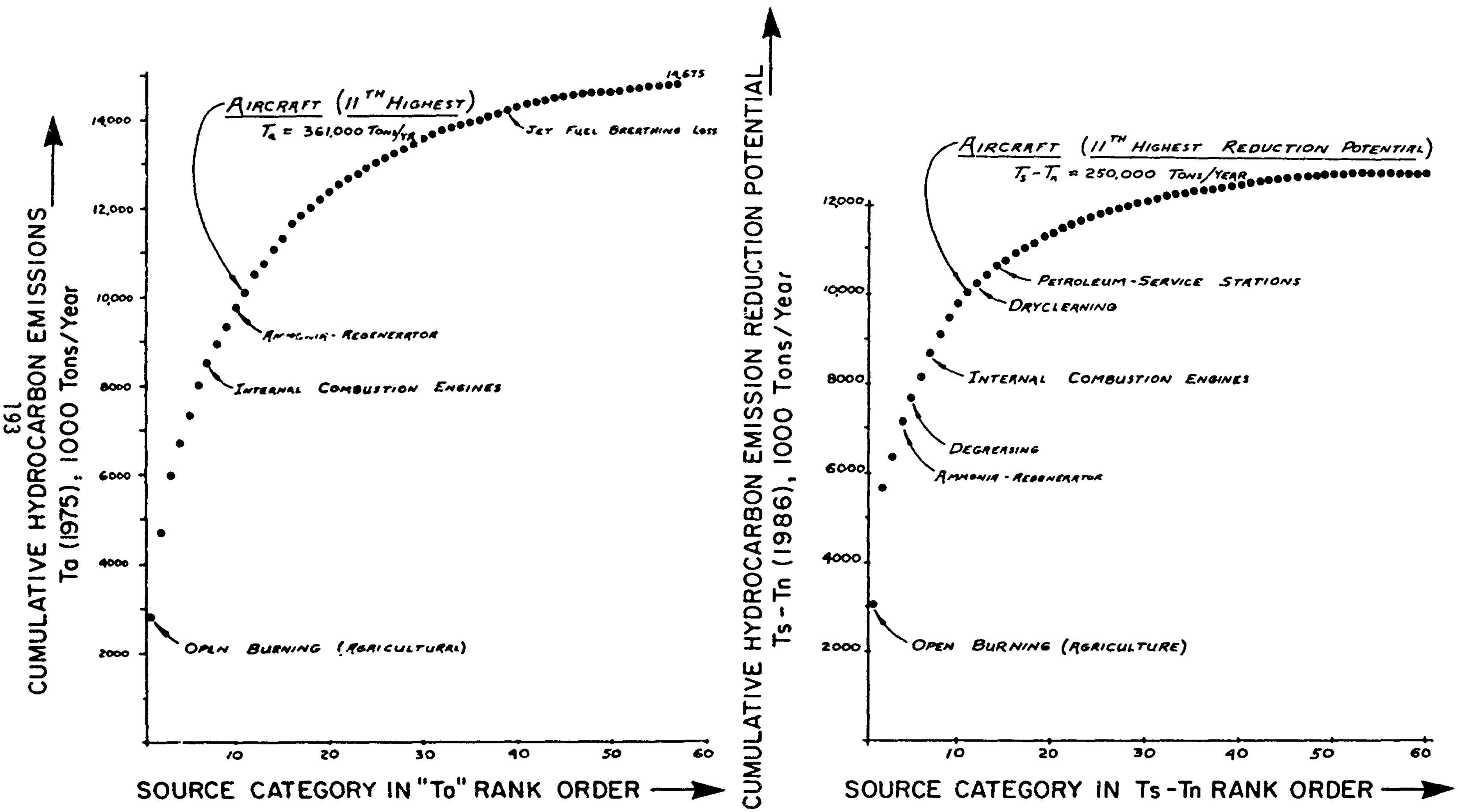
AIRCRAFT CONTRIBUTION TO NATIONAL, REGIONAL, AND AIRPORT EMISSIONS

FIG. 1

traffic are often concentrated in congested terminal areas with reduced potential for atmospheric mixing. Recent measurements of CO in high traffic areas have not suggested serious health problems but further studies may be necessary.(4)

Emission studies as presented in Figure 1 are a good starting point but have other serious shortcomings. The national emissions data is subject to inaccuracies due to the large number of sources and calculations involved in the EPA's National Emission Data System (NEDS). This is especially true for aircraft where the translation of recent emission factor data over many operational modes and many different airport situations can be a complex task. Regional differences in emissions are bound to occur. The 3 percent contribution of the Atlanta airport to regional emissions in Figure 1 appears to be higher than in most regions which are 1 percent or less.(5)

Another way to suggest the severity of aircraft as an air pollution source is by comparison with other source categories. Aircraft emissions are plotted in Figure 2 along with the highest 60 source categories for which EPA is considering New Source Performance Standards (NSPS).(6) Such comparisons are not frequently made since aircraft are regulated in a different part of the federal Clean Air Act and by different divisions within EPA. Aircraft rank as the 11th highest category both when comparing annual emissions and emissions reduction potential (Ts - Tn). The Ts-Tn parameter represents annual emissions which can be reduced from levels with only current control standards (Ts) to levels projected with new or hypothesized control standards (Tn). There are strong pressures for EPA to regulate HC sources since the oxidant ambient air quality standard cannot be met until at least 1987 and then only with a 46 percent reduction in emissions from the 1977 level.(7) This reduction is in addition to strict automotive controls and NSPS already imposed before 1977. The number of sources for which NSPS will ultimately be promulgated remains to be seen but could include many or even most of the sources represented in Figure 2.



COMPARISON OF NATIONAL AIRCRAFT EMISSIONS WITH
"MAJOR" STATIONARY SOURCES
FIG. 2

EFFECT ON AIR QUALITY

Nearly 200 technical reports and papers have been found which contain some evidence related to the effect of aviation on ambient air quality.[(8)] Techniques include emission analyses, dispersion modelling and ambient measurement studies. Unfortunately, each method has flaws which make scientific general conclusions difficult. Emission analyses are readily understandable but are not directly comparable to air quality standards. Dispersion models explicitly relate aircraft emissions to air quality but can become very complex. They also suffer from unknown plume rise and dispersion simulation errors. Ambient measurement data are difficult to interpret since concentrations caused by airports are not readily separated from those caused by other metropolitan sources.

Results of previous studies are too lengthy to include here but are presented in detail in a recent technical report.[(9)] Conclusions by this author based on this report and prior reports are presented in Figure 3. Complete agreement among all investigators is not necessarily expected due to the large and often conflicting body of information which must be integrated. Issues with the greatest technical uncertainty are:

1) The significance that aircraft HC emissions play in the atmospheric formation of photochemical oxidants. Non-methane hydrocarbon concentrations in excess of the 160 microgram per cubic meter air quality guideline have been measured and modelled. This guideline is very crude, however, and no longer recommended by regulatory agencies.

2) The effect of aircraft emissions on maximum short term NO_2 concentrations. The evidence that aircraft could produce hourly NO_2 concentrations in the 0.2 to 0.5 parts per million range is suggestive but certainly not conclusive. The conversion rate of the NO emission to NO_2 in conjunction with atmospheric dilution is not well understood. The short term NO_2 ambient standard, to be used as a measure of health effects, has not yet been issued.

Whether or not any pollutant from aircraft "<u>contributes</u> to adverse health or welfare effects" is therefore still a debatable issue and not easily resolved from current scientific information.

CURRENT EVIDENCE SUGGESTS:

- AIRCRAFT NOT DIRECT CAUSE OF HEALTH & WELFARE EFFECTS (BUT MAY BE A CONTRIBUTOR)

- POLLUTANT PRIORITY

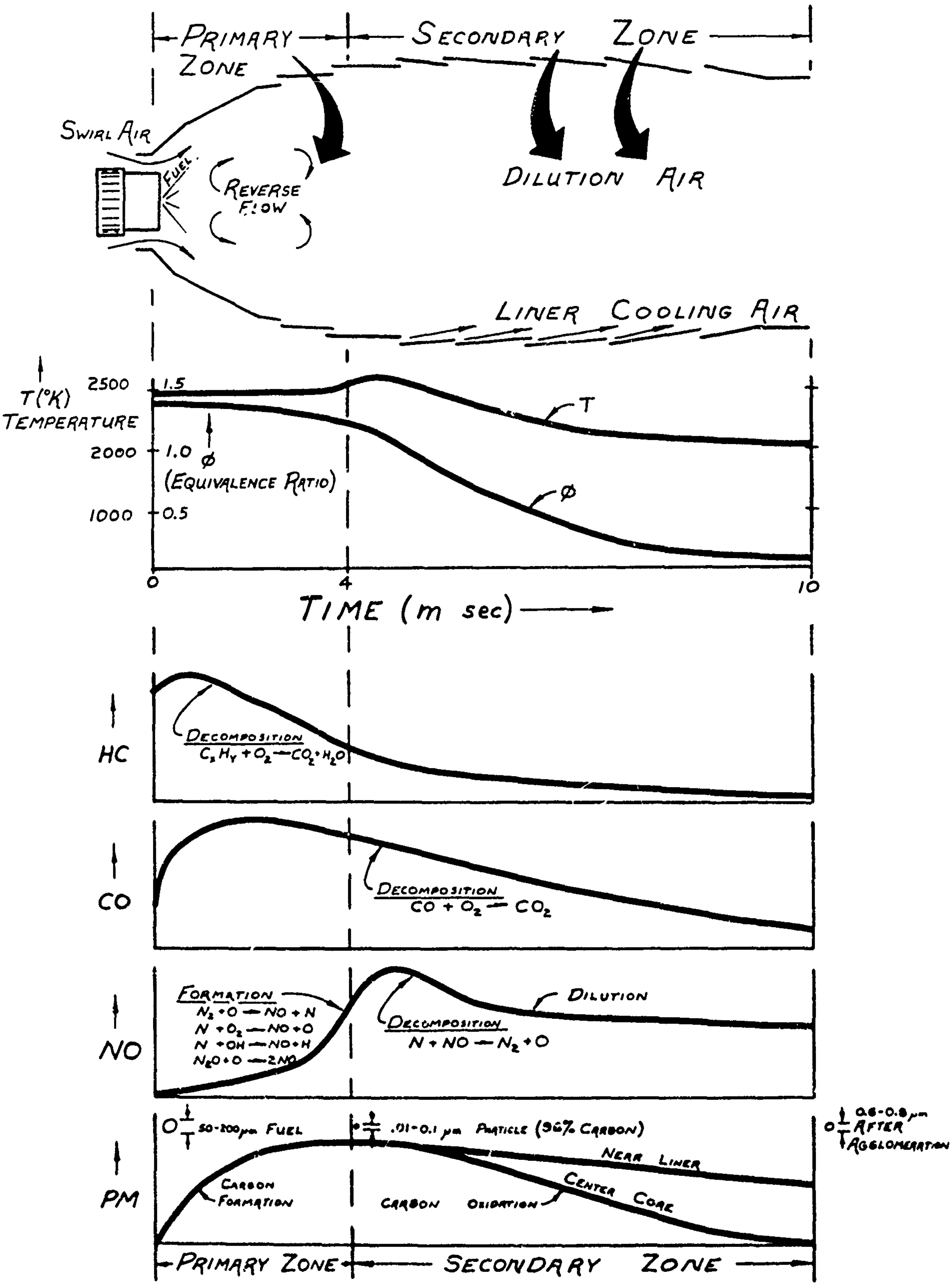
GREATEST CONCERN	• HC --- BASED ON NATIONWIDE O_3 PROBLEMS
	• NO_x--- BASED ON POSSIBLE NO_2 STANDARD
	• SMOKE - CONTROL TECHNOLOGY GENERALLY ADEQUATE
	• CO --- NO PROBLEMS LIKELY
	• SO_x -- NO PROBLEMS LIKELY
LEAST CONCERN	• OTHERS - NO PROBLEMS IDENTIFIED

AIRCRAFT EFFECT ON AIR QUALITY
FIG. 3

POLLUTANT FORMATION AND CONTROL

Debate over the air quality effect of aircraft would be less important if controls could be readily implemented to even further reduce what many consider is now a small emission source. Unfortunately, there are considerable engineering costs involved. A basic understanding of the pollutant formation process is needed to appreciate the control techniques proposed and their difficulties. A sketch of an aircraft engine combustor is in Figure 4. Typical temperatures (T) and equivalence ratios (Ø) are shown. The equivalence ratio is the local fuel/air ratio divided by the stochiometric fuel/air ratio. The primary combustion zone is characterized by high temperatures and fuel rich conditions. Dilution air causes low temperatures and fuel lean conditions in the secondary zone. High HC concentrations in the combustor occur initially as the fuel vaporizes but then rapidly decompose. Carbon monoxide is formed in fuel rich conditions but can be substantially oxidized to CO_2. Nitric oxide (NO) levels are formed at high temperatures when sufficient oxygen is available and are typically "quenched" from decomposition by the cool secondary air flow. Particulate matter is formed when fuel droplets are inadequately vaporized prior to combustion. Oxidation of the 96 percent carbon[10] particulates proceeds unless "frozen" by low temperature air such as near the combustion liner.

The technology for control of aircraft engines is detailed in other sources.[11][12] Some of the approaches are summarized in Figure 5. As with many combustion sources, control of HC and CO with higher combustion temperatures and lean conditions are the opposite conditions desired for the control of NO_x. The complex advanced combustors shown in Figure 5 are required for simultaneous HC, CO, and NO_x control.



GAS TURBINE POLLUTANT FORMATION AND DECOMPOSITION

FIG. 4

CONVENTIONAL COMBUSTOR TECHNOLOGY (HC, CO Control at Idle)

FUEL SECTORING------------------Restrict Fuel to Portion of Combustor
- Better Fuel Atomization
- Higher Flame Temperature

ENRICH PRIMARY ZONE------------------Reduce Primary Airflow for Higher Flame Temperature

DELAY DILLUTION AIR------------------Promote CO Consumption

AIR BLAST------------------Use Venturi to Break-Up Fuel Droplets

ADVANCED COMBUSTOR TECHNOLOGY (NO_x, HC, CO Control)

STAGED FUEL INJECTION------------------Provide both Pilot and Main Stage Ignition
- Higher Flame Temperature at Idle
- Minimize Peak Temperatures at High Power

VARIABLE GEOMETRY------------------Optimize Airflow for Thrust Condition

SUMMARY OF AIRCRAFT ENGINE EMISSION CONTROL TECHNOLOGY
FIG. 5

Implementation of advanced combustor technology to large commercial aircraft engines could cost 1½ to 3 billion dollars over a 10 year period.(13) The question of whether the cost of controls exceed the air quality benefits is difficult to answer. Data in a recent cost effectiveness study(14) suggest that aircraft engine controls for HC and CO of several hundreds of dollars per ton of emission reduction are in line with other EPA control strategies. NO_x controls, possible only with advanced combustor technology, cost a projected $3,400 to $9,700 per ton and are higher than NO_x control strategies for other sources.

EMISSION STANDARDS/GOALS

Numerous revisions to the EPA standards for civil aircraft engines, first issued in 1973,(15) have occurred since then. Changes proposed in 1978(16) are still under consideration. A summary of these proposed standards for gaseous emissions are presented in Table I to illustrate their form and substance. Standards for fuel venting and smoke emissions are less controversial and are not shown. The compliance deadlines indicated will certainly be altered since lead times must be provided after the standards are reissued. The complex format of the standards results from judgements of the "best available control technology" which varies between the engine sizes and types listed in Table II. The mass of emissions per thrust (grams/kilonewton in Table I) is a composite calculation to account for variations in engine modes and aircraft operating conditions.

A simpler set of aircraft engine regulatory emission levels shown in Figure 6 were recently recommended by the International Civil Aviation Organization (ICAO).(17) They would not result in as great an emission reduction but would provide some controls for future engine emissions and would presumedly make engine certification more predictable. They apply to the statistical mean of the engines certified rather than the upper limit intended by the EPA standards. The effect of this ICAO recommendation on revisions to the EPA standards remains to be seen.

Military aircraft engine emissions are not regulated by the EPA standards. The US Air Force and Navy have instead adopted "goals" to limit future engine emissions. Limitations for new engines qualified after 1981 are outlined in Figure 6 and fully described elsewhere.(18) These "goals" are intended to give guidance in the engine design phases where a compromise between many design parameters must be resolved. Engines which are built and fall short of these goals will not necessarily be rejected unless the need to do so is indicated from air quality studies.

TABLE I

GASEOUS EMISSION STANDARDS FOR AIRCRAFT ENGINES (AS OF PROPOSED REVISIONS, MARCH 24, 1978)

EMISSION STANDARDS	APPLICABLE ENGINES	DEADLINES
HC = <30.7grams/kilonewton CO = <237.0 grams/kilonewton NO_x = <70.8 grams/kilonewton	New Engines of Class T5	---- January 1, 1980
HC = or less than: $26.510 \times 10^{-0.006637rO}$ (grams/kilonewton) CO = or less than: $169.47 \times 10^{-0.007462rO}$ (grams/kilonewton)	New Engines of Classes T1,T2, T3 & T4 with: $27 \leq rO^{*} < 90$ In-Use Engines of Classes T2 & T4 with: $53 \leq rO^{*} < 90$	---- January 1, 1981 ---- January 1, 1985
HC = or less than: 6.7 grams/kilonewton CO = or less than: 36.1 grams/kilonewton	New Engines in Classes T2, T3, and T4 with: $90 \leq rO^{*}$ In-Use Engines in Classes T2 & T4 with: $90 \leq rO^{*}$	---- January 1, 1981 ---- January 1, 1985
NO_x = or less than -33.0 grams/kilonewton ----- $-33.0\ (rPR/25)^{0.5}$ ------ exp(rT3/288.15-2.774)	New Engines of Classes T1,T2,T3 & T4 with: $rPR \leq 25$ with: $25 < rPR$	January 1, 1984
HC = <3.3 grams/kilonewton CO = <25.0 grams/kilonewton NO_x = <33.0 grams/kilonewton	Newly Certified Engines In: Classes T1,T2,T3 or T4 with $27 \leq rO^{*}$;	January 1, 1984
HC = <7.8 grams/kilonewton CO = <61.0 grams/kilonewton NO_x = <39.0 grams/kilonewton	Class T5:	January 1, 1984
HC = <0.045 grams/kilowatt CO = <0.34 grams/kilowatt NO_x = <0.45 grams/kilowatt	Class P2 with: $rO \geq 2000$ kilowatts	January 1, 1984

*rO = rated Output in Kilonewtons
**rPR = rated Pressure Ratio
HC = Total Hydrocarbons, CO = Carbon Monoxide, NO_x = Oxides of Nitrogen

TABLE II - ENGINE CLASSIFICATIONS

CLASS	CRITERIA	EXCEPTIONS
P2	All Turboprop Engines	
T1	Rated Thrust <35,600 Newtons	Engines of Class T5
T2	Rated Thrust >35,600 Newtons	Engines of Classes T3,T4, & T5
T3	Engines of JT3D Model Family	
T4	Engines of JT8D Model Family	
T5	Engines designed for supersonic aircraft	

INTERNATIONAL CIVIL AVIATION ORGANIZATION RECOMMENDED REGULATORY LEVELS

HC: $\frac{Dp}{Foo} = 19.6$

CO: $\frac{Dp}{Foo} = 118$

NO_x: $\frac{Dp}{Foo} = 40 + 2\ \pi_{oo}$

SMOKE: $SN = 83.6\ Foo^{-0.274}$
(Not to Exceed SN = 50)

WHERE:

- Dp = Mass emission over aircraft landing and take-off cycle.
- Foo = Maximum thrust at take-off.
- π_{oo} = Maximum pressure ratio.
- SN = Measured smoke number.

US AIR FORCE/NAVY EMISSION GOALS

(For engines qualified after 1981;
Goals for 1979 not shown)

HC, CO: Combustion efficiency greater than 99.5% (engines with idle pressure ratio over 3/1)

Combustion efficiency greater than 99% (engines with idle pressure ratio less than 3/1)

NO_x: Reduction of 50% from uncontrolled level at maximum thrust (uncontrolled level is a function of combustion inlet temperature)

SMOKE: Below visibility threshold (the acceptable smoke number is a function of "nd" where n = number of engines in optical path; d = exhaust diameter)

ICAO REGULATORY LEVELS AND US AIR FORCE/NAVY EMISSION GOALS
FIG. 6

SUMMARY AND CONCLUSIONS

Emission and air quality data suggest that aircraft are a small part of overall air pollution problems. Health and welfare effects directly attributed to aircraft have not been proven. However, neither have this data established that aircraft are an insignificant contributor to pollution on a local scale. A rank order of priorities for control by pollutant specie is suggested in Figure 3. Pollutant formation and control techniques for aircraft engines are briefly described. Different engine regulatory limits and emission goals have been established by the Environmental Protection Agency, International Civil Aviation Organization, US Air Force and US Navy.

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FERNLEITUNGS-BETRIEBSGESELLSCHAFT
mit beschränkter Haftung

October 1980

Measures in the field of Environmental Protection

with a view to Construction and Operation of Pipe Lines and Tank Farms in the Federal Republic of Germany

Industry-Military
Energy Symposium
San Antonio/Texas
Oct. 21-23, 1980

Paper
presented by:
U. Detlefsen

In the individual countries, principles and criteria for operating and building a pipe line are basically identical, although there are differences with regard to individual regulations. As far as the Federal Republic of Germany is concerned, there is much more emphasis on environmental standards than in other European countries and these standards have major impacts on the operation of pipe lines.

The US-Armed Forces in the territory of the Federal Republic of Germany are fulfilling very important and extensive tasks within the Alliance. One of the most essential prerequisites for the implementation of these tasks is a secure fuel supply in times of peace and of tension.

It might therefore be of interest to you to learn something about the construction and operation of military tank farms and fuel pipe lines in the Federal Republic of Germany.

Before coming to my specific topic, I would like to give you a brief historical review.

Until the end of the 1950s, the infrastructure of mineral oil supply in the Federal Republic of Germany was confined exclusively on inland waterways and the railway net. In some regions, this distribution system for processed products was to a limited extent supplemented by roads.

The demand for mineral oil rising, the pipe line developed as a new supply system. This development ensued considerable technical and economic changes with regard to the transport of mineral oil. Apart from the civilian pipe lines - predominantly designed for crude oil transports - a close-meshed military pipe line system was set up in Western Europe in the 1950s in order to assure the supply of NATO Armed Forces with ground fuels and aviation fuels.

...

The year 1957 is the foundation year of Fernleitungs-Betriebsgesellschaft (FBG) which, on behalf of the Ministry of Defence, is operating the NATO pipe line system in the territory of the Federal Republic of Germany. The Central European Pipe Line System of NATO in France, Belgium, The Netherlands and Germany - also called CEPS - comprises approximately 3,700 miles and 60 tank farms of a capacity of 11 million barrels. This system was designed for the transport and storage of the ground fuels Gasoline and Diesel and the aviation fuels JP4 and JP1.
In the territory of the Federal Republic of Germany, FBG is responsible for the operation of the eastern part of the system consisting of some 1,500 miles, 28 tank farms, 27 truck-loading facilities, 7 rail-loading facilities and 42 high-pressure pump stations. The pipe line system supplies 24 American, British and German airbases which are connected to the system via spur lines.

The following table provides a survey of the fuel supply. The system is constructed as a network with mainlines in the west-east direction and numerous cross connections. This net connects the entry points - these are refineries and tank farms at sea harbors - with those facilities at the tank farms where fuel is delivered to the Armed Forces.

The bulk of the fuel is supplied from more than 25 refineries and other civilian installations which are directly connected to the pipe line system.

The possibility of pumping from nodes of the line system into different directions renders the system extremely flexible with regard to the implementation of transports.

After this short survey, I now would like to turn to measures in the field of environmental protection.

...

Beginning in 1960, directly after the commissioning of the first pipe lines, the dense population in the Federal Republic of Germany and the scarcity of groundwater reserves, endangered by a widespread industrialization, have led to the enacting of special regulations on the construction and operation of pipe lines and tank farms. On account of the federal system, these laws were in part promulgated by the state government and partly by the local governments.

Construction and operation are always subject to permission. In order to obtain the respective permits, written applications including extensive calculations, descriptions and technical documentation have to be filed with the competent authorities. The permits can be limited in contents, time and can be subject to a set of stipulations.

While the legal regulations only provide for safety conditions of a more general kind, the concrete technical requirements concerning construction and operation are contained in numerous technical directives.

Taking into account safety influencing factors - such as influences pertinent to facilities and the environment - safety measures can, for the following considerations, be classified as follows:

Primary measures,
aiming at the safety of facilities;

Secondary measures,
aiming at the detection of leaks and the limitation of damaging effects.

The consideration of those factors influencing the building of a pipe line and the primary safety measures resulting from them are already to a large extent making

...

allowance for environmental protection. In this context, I am referring to a careful route selection, the calculation of the strength allowing for additional loads, the selection of appropriate materials and the criteria for pipelaying.

Over and above that, the German authorities are imposing special stipulations for the granting of building permits. I would like to mention some of the most important ones:

First of all, there is the safety factor for the calculation of the wall thickness of the pipe and the resulting allowable operating pressure. In most cases, the pipe materials are predominantly designed for static loads with a safety factor of 1.6 relating to the minimum yield strength. For certain line section, this safety factor was for all materials fixed at 2.0 - in some cases even at 2.4 - for reasons of water protection. This stipulation is considerably effecting the investment costs.

Other stipulations concern:

- the level of pipe cover - usually 1 meter,
- the backfill material to be used in rocky terrain,
- special checks and acceptance inspections of the pipes at the manufacturer's, including hydraulic testing of each pipe with a safety factor of 1.1 relating to the specified minimum yield strength, ultrasonic testing of pipe ends, analysis of the material, testing of insulations. The acceptance certificates must be issued by neutral experts,
- welding conditions, supervision of welding work, examination of the welding personnel,
- 100 % x-ray inspection of all girth welds and, in special cases, additional ultrasonic testing,
- the distrances between remote controlled valves ranging from 3 to 9 miles,
- valve pits which are consisting of an oil- and water-resistant wall construction,

...

- the installation of local oil barriers in waters along the pipe line and, in special cases, also groundwater observation wells,
- and finally, active and passive corrosion protection measures.

I am mentioning this last, perhaps self-evident point because the number of potential test points by which the efficiency of cathodic protection is measured has been highly increased as compared to the past. These test points are installed at intervals of appr. 1.2 miles and additional pipe current measuring points are spaced every 3 miles along the line.

Having cited some of these numerous stipulations, I would now like to talk of operational measures with a view to environmental protection.

Although extensive precautionary measures are taken during planning and construction in order to assure safety, a line damage cannot be ruled out completely. In this context, I am especially referring to outside factors. Therefore, leak detection, location an limitation equipment has to be provided for.

Among other things, the following stipulations have been laid down for the supervision of the line during pumping operations and during non-operating hours:

1. equipment permanently measuring and recording flow volumes and pressures,
2. two systems working continuously and independently which are detecting leaks during steady state,
3. equipment which allows to find out at weekly or monthly intervals whether slight leaks have occured,
4. a system for quick leak detection.

Taking an appr. 90-mile long pipe line section as an example, I would like to demonstrate the functioning of this equipment which is shown in the following chart.

...

The nominal diameter is 8 inch, the operating pressure is 1,100 psi with a throughput of 970 gal./min.

a) At both sides of the line, turbine meter accurate to 0.3 % are installed for flowmetering. Measuring points have been installed at 13 places in the pits. Measured data are continuously transmitted to a control center at a 100-mile distance via rental lines provided by the German postal system.

b) Flows metered are compared by an electronic comparison system. Following a throughput of 26 gallons, both meters produce electronic pulses. A difference of 20 pulses release an alarm in the supervisory center and a difference of 40 signals leads to a shutdown of pumping operations. At this time, the size of the leak would be approximately 1,100 gallons. With regard to the chosen example, leaks of a size of appr. 2,600 gal./hr. and larger can be detected in this way.

c) In addition to this quantity control, there is a pressure control at 17 measuring points. Pressure change, resulting from leaks are also transmitted to the control center and are evaluated there. If thresholds which are empirically calculated and which depend on the location of the leak are reached, an alarm is also triggered and pumping operations are shut down. This procedure is less accurate and permits to detect leaks of a size of 4,000 to 8,000 gal./hr. and larger.

d) The aforementioned instruments are also used for leak detection. In the event of a leak, there is a pressure drop depending on the size of the leak which produces a negative pressure wave travelling to both sides - that means, to the suction and the discharge side. Pressure changes and different travel times are evaluated by electronic equipment. By these procedures, leak detection of ± 1.5 miles is made possible - however, for this line section chosen, only leaks as large as 3,000 gal./hr. can be detected.

e) Slow leakages of 3 gal./hr. during non-operating hours can be detected by means of evaluating pressure and temperature changes of the product which are also relayed.

In connection with additional requirements, such as:

- high degree of availability of circuit lines,
- high reliability of all equipment,
- standby power supply for flowmeters and the control center,

...

- short transmission times,
- little maintenance requirements,
- easy removal of faults,

these secondary safety measures are associated with high investment and operating costs. With regard to maintenance work, they require especially trained personnel, because a breakdown of these facilities would mean a stardstill. It has been established by the authorities that operations have to be shut down immediately if the safety of the pipe line can no longer be ensured. If, for example, it is no longer possible to have a flow comparison because of a failure of the turbine meter or of the transmission equipment, operations have to be stopped.

Legal regulations stipulate a regular check of all operational safety equipment to be carried out by neutral experts of Technical Supervisory Agencies. The intervals at which checks have to be performed amount to one or two years for the aforementioned equipment directly pertinent to safety, to three years for cathodic and lightning protection facilities and to five years for storage tanks.

Deficiencies discovered at the facilities will be laid down in a test report and will be reported to the licensing authorities. At any time, the authorities are entitled to fix deadlines for the removal of deficiencies and to demand additional measures.

The building of military pipe lines and tank farms in the Federal Republic of Germany has not yet been completed. The pipe lines built in the mid-sixties were the first lines to be provided with safety equipment.

At present, the older pipe lines are also being supplied subsequently with this equipment.

...

I would now like to turn to environmental measures relating to tank farms. Since, as I have already mentioned, it is military facilities that are concerned, the design of the tanks differs considerably from that of civilian tanks. The following picture shows the typical design of a NATO storage tank. The tanks are semi-buried; steel walls and steel floor are surrounded by a concrete shell. The capacity of the tanks varies from 16,000 to 66,000 barrels. Building and operation of these tanks with their connections to the manifolds as well as that of the small-sized tanks is also subject to the approval of the authorities.

Out of the large number of environmental measures relating to tank farms, I just would like to mention the most important construction measure.

Legislation calls for double walls for all buried tanks or equivalent measures. Steel tanks with a concrete shell are only allowed if it is possible to monitor the intermediate space for leaks; this applies especially to the concrete foundation and the steel floor of the tank. On the picture, this intermediate space is marked in red. A check pipe leads from the low point underneath the steel floor to a fuel separator with an oil probe which, when in contact with oil, releases an alarm. This requirement relating to the construction of new tanks has been considered since the 1960s, but there are several tanks built before 1960 without an intermediate space.

As stipulated by law, these tanks have to be supplied subsequently with a second tank floor - in some cases even with an additional tank wall - and with leak detection equipment.

Let me conclude with a few remarks on damage control in the event of a leak on the pipe line.

...

Measures to be taken in the event of a leak have been laid down in an oil alarm plan. This plan provides for the necessary immediate measures to be taken for all kind of damages. It contains all internal and external departments to be informed, topographic charts on which pipe line routes and oil barriers have been marked and lists also kind and storage place of oil fighting equipment and materials. Oil fighting is either performed by the local fire brigades in cooperation with the staff of the facilities or, as is the case with some civilian companies, by fire brigades which are assisted by outside contractors. Responsibility for the action lies with the fire brigades. Oil and fire fighting personnel has to be permanently on call.

In most of the Federal Laender in the Federal Republic of Germany, the fire brigades already dispose of oil fighting equipment. Additional pipe line material for this purpose is being stored by the operating companies.

Some Federal Laender have decided that the responsibility for exact detection of leaks and for damage control lies exclusively with the fire brigades. For these tasks, the fire brigades in communities situated along the pipe line route are to be supplied with vehicles, equipment and materials which are partly or completely financed by the pipe line companies. Out of the large number of individual items, I would like to mention a few such as: fire-fighting vehicles, mobile fuel separators, pneumatic boats, floating oil barriers, walkie-talkies, collecting tanks and oil containment material.

The efficiency of these oil-fighting measures is checked once a year in a so-called "Oil Alarm Exercise" which is initiated by the authorities.

...

I am coming to the end of my remarks. Environmental protection has nowdays become an accepted fact and an imperative necessity and this applies to almost all sectors of the infrastructure of a country. The special requirements embodied in strict regulations can only be met if planning, construction, operation and supervision of pipe lines and tank farms are already taking into account every possible measure which can help to assure and maintain the safety of these facilities and thus contributes to the safeguarding and preservation of environmental resources.

It is impossible to give a comprehensive survey of this topic in a few minutes; nevertheless, I hope that I have succeeded in informing you of the most essential aspects.

EFFECTS OF EPA REGULATIONS

on the

OIL INDUSTRY

Michael Rusin
Manager Industry Analysis - API

Presentation not available at time of printing

AN OVERVIEW OF FUEL QUALITY MONITORING

TO BE PRESENTED AT

THE U.S. AIR FORCE
INDUSTRY/MILITARY ENERGY SYMPOSIUM
SAN ANTONIO
OCTOBER 21-23, 1980

R. T. HOLMES
SHELL OIL COMPANY

AN OVERVIEW OF FUEL QUALITY MONITORING

Aviation turbine fuel is probably the most rigidly controlled bulk product produced in our refineries. Some 16 industry specification properties, and additional in-house tests, controlling composition and performance, are met before shipment from the refinery. These critical properties are maintained throughout an extensive multi-product distribution system and augmented by additional cleanliness testing as the fuel approaches it's airport destination. The fuel is repeatedly filtered and settled at the terminal and airport facilities to remove various contaminants, which might have been introduced in the distribution system. Finally, monitoring of product quality and cleanliness at these facilities assures the delivery of clean, dry specification fuel to the aircraft. The techniques and equipment used in this final quality monitoring are a critical link in the system and are the subject of this review.

Product cleanliness is usually defined in terms of free water, surfactants, particulates (dirt, rust, etc.) and microbial contamination. Free water is of greatest concern since it is the common denominator in most cleanliness related problems, i.e., free water is a necessary component for microbial growth, rusting, particulate suspension and in combination with surfactants, is the primary cause of filter and coalescer failures. The cleanliness requirements for commercial turbine fuels are not rigidly defined. However, recent discussions have indicated the upper acceptable limits indicated in Table I.

Terminal/Airport Facilities

A typical terminal/airport filtration system is shown in Figure 1. These facilities use a combination of in-tank settling and filter/coalescer (F/C) units to remove free water and particulates. Clay filters and additional

micronic filtration may be used to further control free water/particulate levels and to reduce surfactant levels. These units are designed to reduce contaminants to the following approximate levels.

Contaminant	Clay Filter	Filter/Coalescer
Free water	< 15 ppm	< 15 ppm
Particulates	< 10 μ	< 2 μ
Surfactants	85+ WSIM	--

Accordingly, these in-line filtration systems function as a primary control and monitoring system in providing clean, dry fuel to the aircraft.

The continued collection of contaminants by the filter and coalescer units will result in their eventual failure and possible release of contaminants to the downstream system. Hence, an variety of monitoring techniques are used in determining their effectiveness and potential need for replacement. The principal failure modes for clay filters and current methods of detection are indicated in Table II. Clay filters are generally monitored by examining the downstream product cleanliness. The need for replacement of clay filters is indicated by a failure to improve the fuel cleanliness as indicated by comparative measurements of free water, particulate levels or surfactant effects taken upstream and downstream of the filter. The appearance of these contaminants at the downstream coalescer, or failure of the coalescer, indicates a need for replacement of both units.

The detection methods include two new test procedures now in field evaluation by the Fuel/Water Separation Group of the Coordinating Research Council (CRC). The Side Stream Sensor technique[1] uses a miniature clay filter mounted in parallel to the parent unit and receiving the same unit volume of fuel. The test filter is easily removed and interrogated as an indication of the current condition of the parent filter. This technique is further described in a recent SAE Paper No. 800771. The Delta Time Test[2] is an adaptation of the USAF Filtration Time Test and compares the time for a given volume of fuel to pass through a membrane filter at constant pressure, when sampled before and after the clay filter. The test method appears to detect surfactant/water breakthrough after the clay is saturated.

The principal failure modes for Filter/Coalescer units and the current methods of detection are shown in Table III. Experience has indicated that failure to adequately coalesce water occurs only after exposure to a combination of free water and surfactants. Coalescer failure may be indicated by downstream measurement of free water or indication of particulate release. However, single element testing of a representative element provides the only positive indication of failure. Although water slug tests attempt to duplicate single element testing in-situ, the equipment requirements and potential hazard of introducing free water to the fuel system, have made this approach impractical. A second Side Stream Sensor[1] technique uses a miniature section of a coalescer, receiving fuel at the same unit flow rate as an indicator of the condition of the parent unit. The test sensor is interrogated in a water separation test, using a standard test fuel, as an indication of the condition of the parent coalescer. This new technique is also in field evaluation by the CRC Group.

1 Developed by Exxon Research and Engineering.
2 Developed by Gammon Technical Products Co.

Although several of these monitoring techniques have been adopted for continuous operation, there is a continuing need for a simplified and reliable continuous monitor to detect and react to unsatisfactory levels of free water and particulates. This monitor, to be located downstream of the primary filter/coalescing system, would provide a final assurance of satisfactory fuel entering the dedicated airport system. Various forms of turbidity meters and water sensitive monitors have been examined with several "fuse" designs based on water absorbent materials (paper) showing the greatest promise. However, this design has generally not allowed sufficient sensitivity for rapid shut-down with unacceptable free water levels (over 50 ppm) without occasional shut-down at continuous exposure to lower acceptable free water levels (10 ppm). In addition, continuous exposure to surfactant containing fuels may "water proof" the water absorbing element, rendering it inoperative. A more recent fuse design uses a new fiber having an unusually high capacity for water absorption and apparent sensitivity of the desired level. An initial examination of this design has shown favorable performance and the field evaluation is continuing.

Finally, in reexamining the current "state-of-the-art", there is indication that further improvements might be made in coalescing and monitoring techniques.

- There is a continuing need for improvement in the usable life of coalescing elements. Recent developments in oil separation coalescers have suggested advantages in alternate fibers or fiber coatings and the use of Zeta potential forces in improving coalescence. Has this technology been thoroughly examined in relation to water separation coalescers?

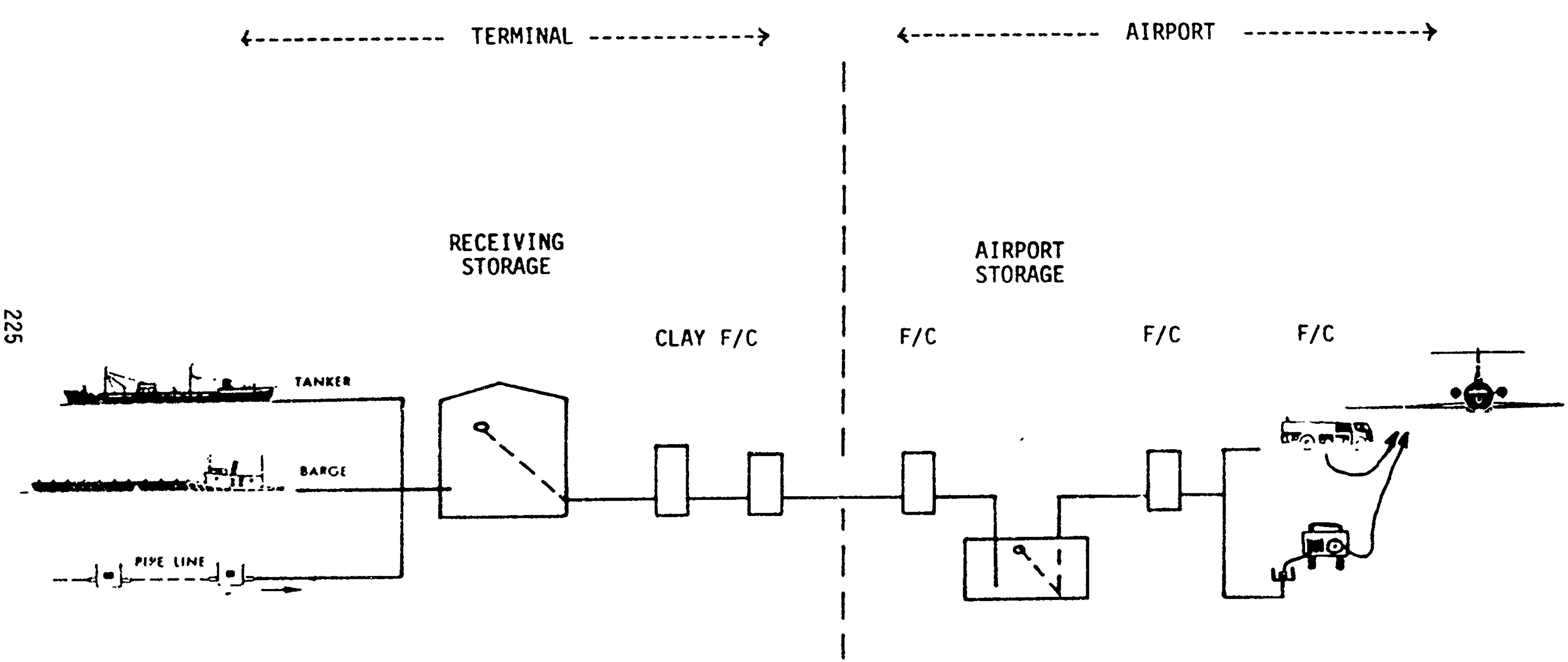
° The previously mentioned water absorbing fibers offer some interesting potential as alternates to coalescers. For example, would these units be more satisfactory as the final filter/monitor replacing the coalescer on refuelers and hydrant carts?

TABLE I

AVIATION TURBINE FUEL CLEANLINESS PARAMETERS

CONTAMINANT	ENGINE MANUFACTURERS	AIRFRAME MANUFACTURERS	AIRLINES	ASTM D-1655	IATA GUIDELINES
Free Water	Suggest less than 15 ppm - well dispersed.	Suggest less than 15 ppm.	Free from undissolved water.	Free from undissolved water - bright and clear.	< 30 ppm free water.
Particulates	1.0 mg/l max. < 10 size.	1.0 mg/l max.	0.5 mg/l max. #4 color max.	Free from sediment and suspended matter	1.0 mg/l max.
Surfactants	Pass water reaction test. Suggest WSIM above 85 (70 with anti-static additive).	Pass water reaction test. Report WSIM.	Pass water reaction test. Report WSIM and membrane filter color - check F/C life	Pass water reaction test. Clear and bright	Pass water reaction test. 85 min. WSIM (70 with anti-static additive)
Microbial Activity	Free of sediment and nauseating odor - suitable for use in aircraft engines.	Suggest fuel be "sterile".	Free of sediment and nauseating odor - systems checked frequently and biocides used as required.	Free of sediment and nauseating odor.	Free of microbial contamination.

FIGURE 1: TYPICAL TERMINAL/AIRPORT FUEL SYSTEM



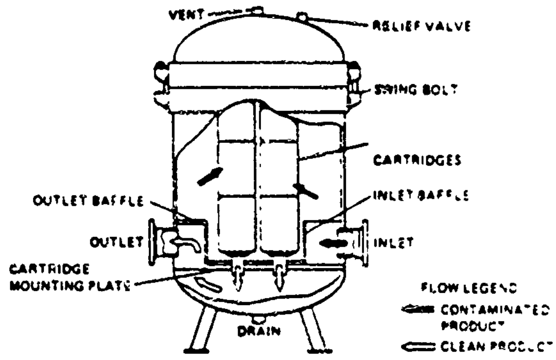


TABLE II - CLAY FILTER FAILURE MODES AND METHOD OF DETECTION

FAILURE MODE	DETECTION
° FILTER BLOCKAGE, REDUCED FLOW	° Δ P MEASUREMENT ° FLOW MEASUREMENT
° RUPTURED OR BY-PASSING CLAY BAGS/CANNISTERS	° COLOR MEMBRANE TEST ° Δ P MEASUREMENT ° INCREASED Δ P AT DOWNSTREAM COALESCER
° CLAY SATURATED BY SURFACTANTS/ WATER	° Δ P INCREASE ° COLOR MEMBRANE TEST ° DIFFERENTIAL MEASUREMENTS - SURFACTANT LEVELS WSIM, MSS, M-SEP., CVDT - FREE WATER ° DOWNSTREAM DETECTION OF FREE WATER, PARTICULATES ° FAILURE OF DOWNSTREAM COALESCER ° SIDE STREAM SENSOR TEST(1) ° DELTA TIME TEST (2)

(1) EXXON R&E PROPOSED TEST METHOD - NOW IN CRC FIELD TEST.

(2) GAMMON TECHNICAL PRODUCTS PROPOSED TEST METHOD - NOW IN CRC FIELD TEST.

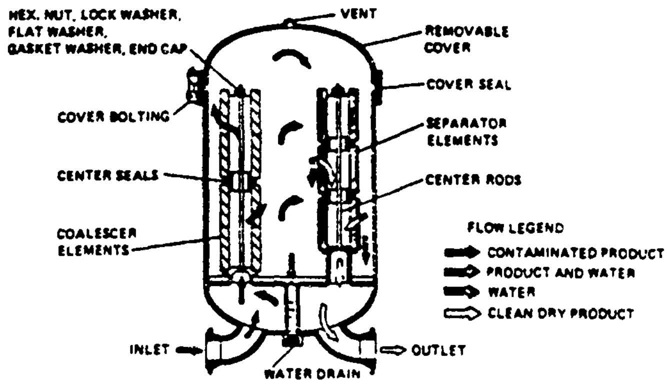


TABLE III - COALESCER FAILURE MODES AND METHOD OF DETECTION

FAILURE MODE	DETECTION
° FILTER BLOCKAGE, REDUCED FLOW	° Δ P MEASUREMENT ° FLOW MEASUREMENT
° RUPTURED OR BY-PASSING ELEMENTS	° COLOR MEMBRANE TEST ° Δ P MEASUREMENT
° FAILURE TO COALESCE FREE WATER	° SINGLE ELEMENT TEST ° IN-SITU WATER SLUG TEST ° FEIB (WATER WASH) TEST ° DOWNSTREAM WATER DETECTION - WATER MONITOR FUSE SHUT-DOWN - APPEARANCE IN DOWNSTREAM COALESCER - VARIOUS WATER DETECTION TESTS ° SIDE STREAM SENSOR TEST(1)
° FAILURE TO RETAIN PARTICULATES	° COLOR MEMBRANE TEST ° PARTICULATE MONITOR FUSE SHUT DOWN ° APPEARANCE OF DOWNSTREAM SAMPLES

(1) EXXON R&E PROPOSED TEST METHOD - NOW IN CRC FIELD TEST.

ARMY FUELS PROGRAM

MAURICE E. LePERA
US ARMY MOBILITY EQUIPMENT
RESEARCH & DEVELOPMENT COMMAND

THE US ARMY'S FUELS PROGRAM

by M. E. LePera

Recent thrusts within DOD have focused on development and implementation of a Defense Mobility Fuels Action Plan directed towards minimizing potential loss of Military effectiveness that would inevitably result from a disruption of energy supplied under foreign control. The program as developed is responding to this DOD thrust.

Within the Department of the Army, the Mobility Equipment Research and Development Command (MERADCOM) has been delegated the lead role in fuels research, development, testing, and evaluation (RDTE). VU-1 identifies the structure within the Army, whereas, VU-2 provides a means to illustrate the responsibility of the fuel developer with the two major activities within DA involved in engine development; the Tank-Automotive Research and Development Command (TERADCOM) and the Aviation Research and Development Command (AVRADCOM). To effectively conduct any program coordination within DA, DOD, and industry is essential and a prime requirement. VU-3 provides a listing of committees under which this coordination is maintained.

As a background, VU-4 lists the two documents which prescribe Army fuels in terms of their primary, alternate, and emergency use. The fuel policy is currently contained within AR 703-1 as is shown on VU-5. As is noted, JP-4 is the primary fuel for all Army turbine-powered aircraft systems. VU-6 provides a summary listing of our current turbine-powered aircraft and their powerplant systems. VU-7 further lists the population densities of these aircraft. As is noted, the AH-1, OH-58, and UH-1 represent the highest density within the fleet. The Army also has reciprocating powered aircraft within the fleet, but these are not being addressed as they represent a relatively small number of aircraft systems.

The current thrusts within the Army Fuels Program are listed on VU-8. These efforts which involve aviation systems are the following:

- Develop capability for using synthetic and alternative fuels.
- Develop new, accelerated fuel-engine qualification procedure methodology.

The other efforts will not be addressed since they are primarily directed towards ground equipment systems.

The above two thrusts have evolved from the recent emphasis within DOD as was stated previously. Prior to discussing the synthetic fuels program underway, a brief explanation of the systematic process is needed to identify those steps needed prior to field or fleet testing a new or modified fuel. Initially, there exist numerous concerns relative to overall performance of new fuels. These are listed on VU-9. In addition to those listed, there are Military requirements which exist which must be considered within any developmental program. These can be summarized as follow:

- Survivability - Fuels must be designed to reduce the threat/vulnerability of fuel fires produced by ballistic penetrations.

• Commonality - Fuels must have interchangeability and interoperability characteristics to comply with NATO standardization policies.

• Storage stability - Fuels must be formulated to possess enhanced storage stability characteristics to minimize potential for deterioration/degradation. Unusually long use intervals exist because of intermittent operation bulk petroleum movements, storage requirements, etc., all of which stress fuel in terms of auto-oxidation.

• Multipurpose use - Fuels must be capable of being used in operations world-wide. One cannot depend on changes in geographical/climatogical environments as fuels must provide for satisfactory operation.

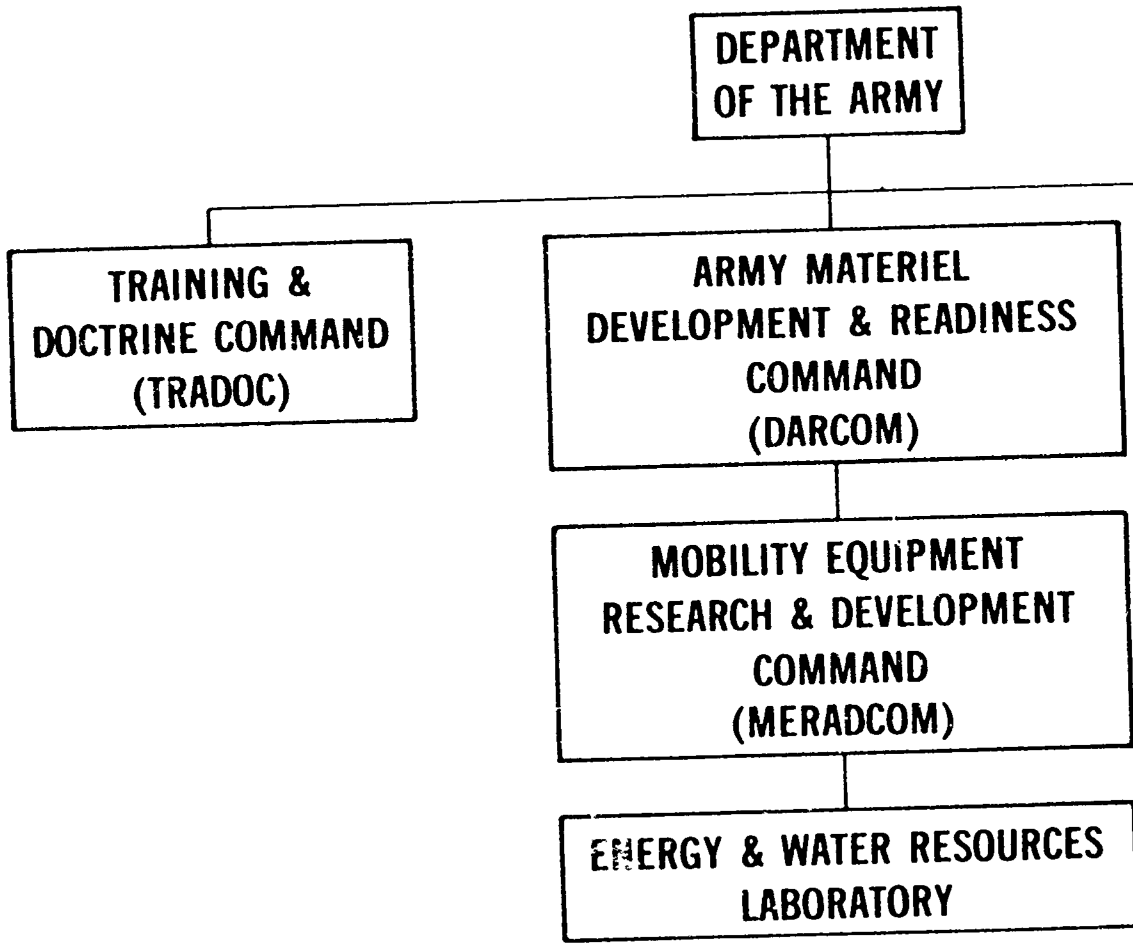
• Unique inhibitor requirements - The types of operational/environmental situations dictate the use of specific inhibitors. Examples are fuel system icing inhibitors, antioxidants, lubricity additives, biocides static dissipator additives, etc.

The actual process involved for development of new fuels is shown on VU-10. The activities participating within Department of the Army to accomplish this goal are shown on VU-11. The program on shale fuels RDTE is briefly summarized on VU-12. The process followed in evaluating new/synthetic fuels allows for the defining of problems in performance prior to the procurement of the large quantities required for engine/component durability testing. The total emphasis and thrust leads to the development of fuel specification(s) which can be used for procurement of products refined from the synthetic crude source which in the near time frame will be shale. Limited quantities of JP-5 turbine fuel and diesel fuel have been obtained from the Parahoe above-ground retort system. This product is being used in the laboratory and component-type RDTE. During FY81, larger quantities of shale-derived product will come available for the durability and endurance testing. These products may be refined from a modified in-situ retorting process. Also, during late FY81, following completion of the engine durability and fuel handling/distribution test phases, field user acceptance tests will be initiated. These tests will continue through FY82 with additional testing in the laboratory being conducted as needed. The field tests will terminate at the end of FY82 with the development and issuance of fully-coordinated fuel specifications for combat gasoline and diesel fuel which in turn will be used by Defense Logistics Agency for procurement of shale-derived product. The current status of those efforts primarily directed towards aviation systems is summarized on VU-13.

The second major thrust within the Fuels Program involves the parallel development of a new accelerated engine-fuel qualification procedure methodology (VU-14). The task which DOD specified in late 1979 (VU-15) was "to develop more efficient Military fuel qualification procedures to effect capacity to react quickly to changes encountered in the petroleum refining industry." VU-16 and VU-17 summarize the rationale for this thrust. The normal time required for qualification of a new fuel for the engine and powerplant accessory systems is approximately five to eight years. As an example, the transition to unleaded gasoline within the Department of the Army took four to five years. VU-18 lists the major aspects to be addressed within this task. The program underway involves five tasks (VU-19). These tasks initially address the survey of what propulsion and accessory systems currently exist within our fleet/equipment inventory. This will be followed by an assessment of the current procedures which are now employed to qualify/certify these systems. For example, there are Military specifications, Military standards, industry standards, etc.,

which are now part of the current procedures. Following this task, an effort will be made to establish relationships/correlations between fuel property characteristics and engine and/or hardware components. For example, certain types of aromatics in jet fuels affect fuel lubricity characteristics; sulfur/nitrogen compounds affect deposition rates in critical area environments, etc. Within this task, new instrumental analyses techniques will be developed to determine/identify hydrocarbon and non-hydrocarbon constituents in fuels that then can be used in the development of more accurate predictive correlations for performance. The fourth task will involve the development of referee and reference fuels which would be used in the accelerated qualification procedure systems. The use of these fuels is most critical in any accelerated evaluation as they would assure the adequacy of any developed qualification/certification test. The last task would essentially involve the development of the accelerated qualification procedure methodology. This methodology, once developed, would be updated with new test techniques, software and modeling procedures as these become available. The procedures would also be implyed to evaluate the resultant performance of alternative/emergency type fuels that become available. VU-20 summarizes the current status of this recently initiated effort.

In summary, the Army Fuels Program shows, (1) the increased emphasis in synthetic fuel RDTE, (2) a certain degree of flexibility for addressing all types of synthetic fuels, and (3) the new effort to reduce the time required for qualifying new fuels on engine/component systems.


DEPARTMENT OF THE ARMY
TRAINING & DOCTRINE COMMAND (TRADOC)
ARMY MATERIEL DEVELOPMENT & READINESS COMMAND (DARCOM)
FORCES COMMAND (FORSCOM)
MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND (MERADCOM)
ENERGY & WATER RESOURCES LABORATORY

VU-1

ARMY MOBILITY FUELS AND FUELS RELATED RDTE

GROUND EQUIPMENT

TARADCOM

- ENGINE DEVELOPMENT
- INVESTIGATE MULTIFUEL ENGINE CAPABILITIES
- ENGINE QUALIFICATION

AVIATION EQUIPMENT

AVRADCOM

- ENGINE DEVELOPMENT
- INVESTIGATE MULTIFUEL ENGINE CAPABILITIES
- ENGINE QUALIFICATION AND AIRWORTHINESS

MERADCOM

- FUELS TECHNOLOGY AND SPECIFICATION DEV.
- FUEL HANDLING EQUIPMENT TECHNOLOGY
- GROUND SUPPORT EQUIPMENT TECHNOLOGY

READINESS COMMANDS INVOLVED: TSARCOM AND TARCOM

10-2

ARMY FUELS PROGRAM
COORDINATION ACTIVITIES

- JLC'S JOINT TECHNICAL COORDINATING GROUP- AIRCRAFT SURVIVABILITY
- COORDINATION GROUP ON GOVERNMENT AVIATION FUELS RDTE (DOD, NASA, AND DOT)
- AVRADCOM/TARADCOM/MERADCOM SEMI-ANNUAL TECHNICAL PROGRAM INTERCHANGE
- FEDERAL AD HOC INTERAGENCY COMMITTEE ON ALCOHOL FUELS (DOE, GSA, AND EPA)
- NATO MILITARY AGENCY FOR STANDARDIZATION'S ARMY, AIR, AND NAVAL FUELS AND LUBRICANTS WORKING PARTIES
- AIR STANDARDIZATION COORDINATING COMMITTEE WORKING PARTY 15 - FUELS AND LUBRICANTS
- ASTM & SAE TECHNICAL COMMITTEES & WORKING GROUPS

DOCUMENTS GOVERNING FUEL REQUIREMENTS

ARMY REGULATION AR 703-1 - COAL & PETROLEUM PRODUCTS SUPPLY & MANAGEMENT ACTIVITIES

ARMY TECHNICAL BULLETIN TB 55-9150-200-24 - ENGINE & TRANSMISSION OILS, FUELS & ADDITIVES FOR ARMY AIRCRAFT

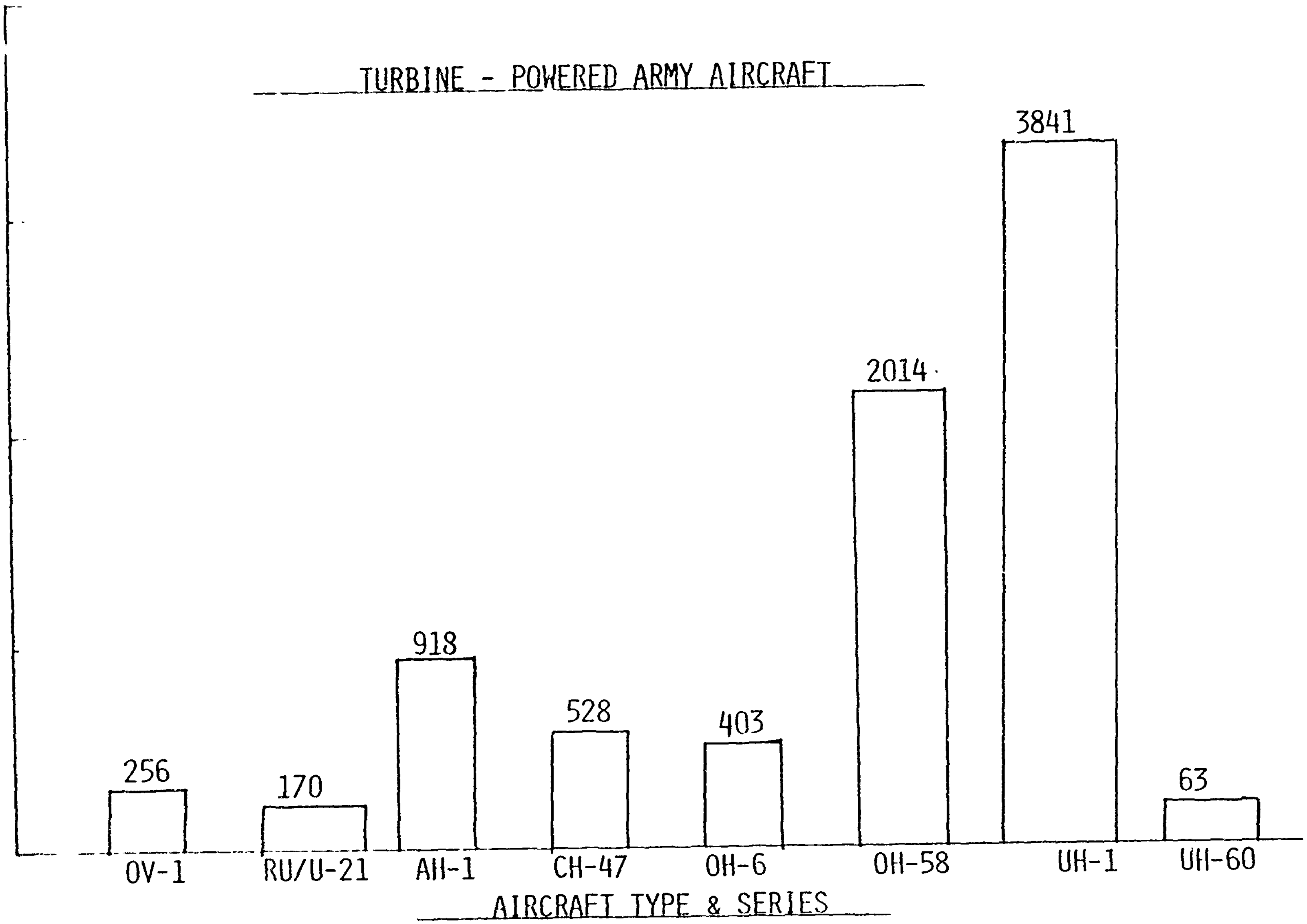
ARMY FUEL POLICY (AR 703-1)

PRODUCT	MILITARY SPECIFICATION	PRIMARY USE
AVIATION GASOLINE (AVGAS)	MIL-G-5572, 100/130 (NATO F-18)	RECIPROCATING ENGINE-POWERED AIRCRAFT
AUTOMOTIVE GASOLINE:		MOBILE & STATIONARY SPARK IGNITION-POWERED GROUND EQUIPMENT
(MOGAS UNLEADED)	VV-G-1690	
(MOGAS LEADED)	MIL-G-3056 (NATO F-46)	
TURBINE FUEL	MIL-T-5624, JP-4 (NATO F-40)	ARMY TURBINE ENGINE-POWERED AIRCRAFT
DIESEL FUEL	VV-F-800 (NATO F-54)	MOBILE & STATIONARY COMPRESSION IGNITION & TURBINE-POWERED GROUND EQUIPMENT

TURBINE - POWERED ARMY AIRCRAFT

AIRCRAFT SERIES	ENGINES
OV-1	T53-L-7 T53-L-7/15 T53-L-701
RU/U-21	T53-L-701 T74-CP-700 PT6-A-20/41
AH-1	T53-L-13B T53-L-703
CH-47	T55-L-7B/7C/11A
OH-6	T63-A-5A/700
OH-58	T63-A-700/720
UH-1	T53-L-13B
UH-60	T700-(GE-700)

TURBINE - POWERED ARMY AIRCRAFT



ARMY MOBILITY FUELS PROGRAM

MAJOR THRUSTS

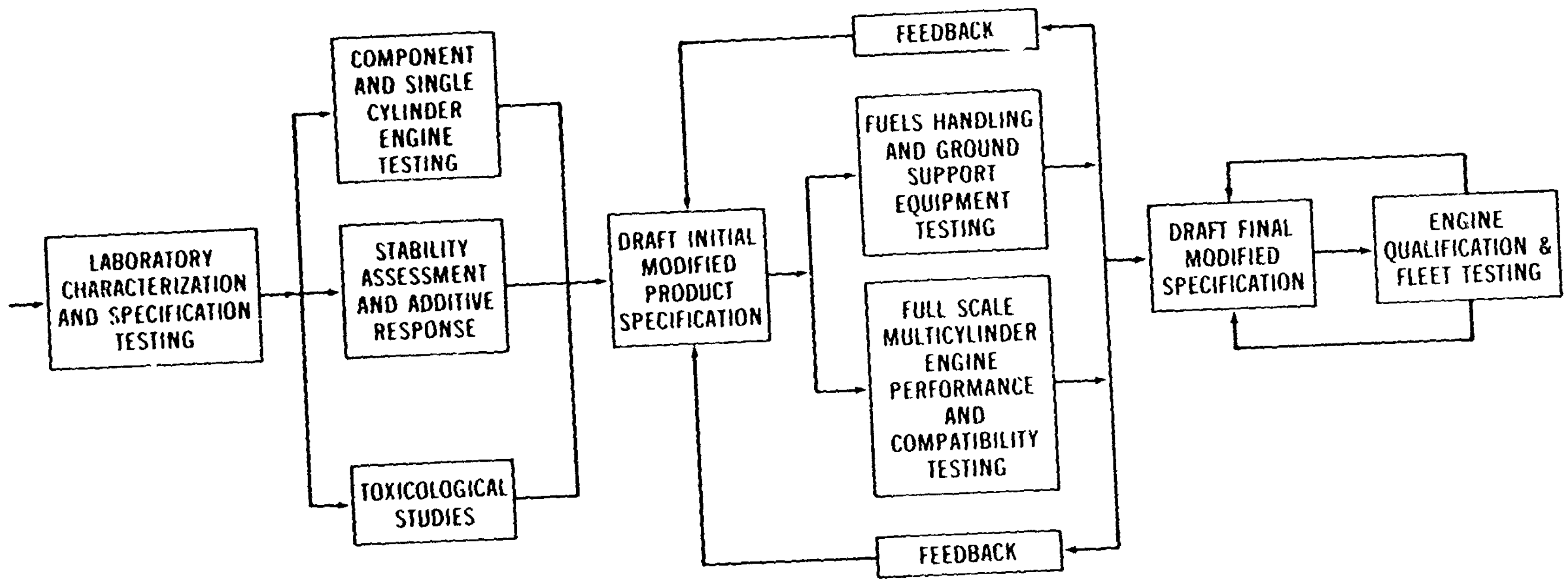
- DEVELOP CAPABILITY FOR USING SYNTHETIC AND ALTERNATIVE FUELS
- DEVELOP SPECIAL PURPOSE FUELS – FIRE RESISTANT FUEL
  – HIGH ENERGY FUEL
- IMPROVE FUEL QUALITY AND STORAGEABILITY
- CONDUCT GASOHOL EVALUATION AND ISSUE SPECIFICATION
- DEVELOP NEW, ACCELERATED FUEL-ENGINE QUALIFICATION PROCEDURE(S) METHODOLOGY

MOBILITY FUEL PERFORMANCE PROPERTIES

AREAS OF CONCERN — NEW OR MODIFIED FUELS

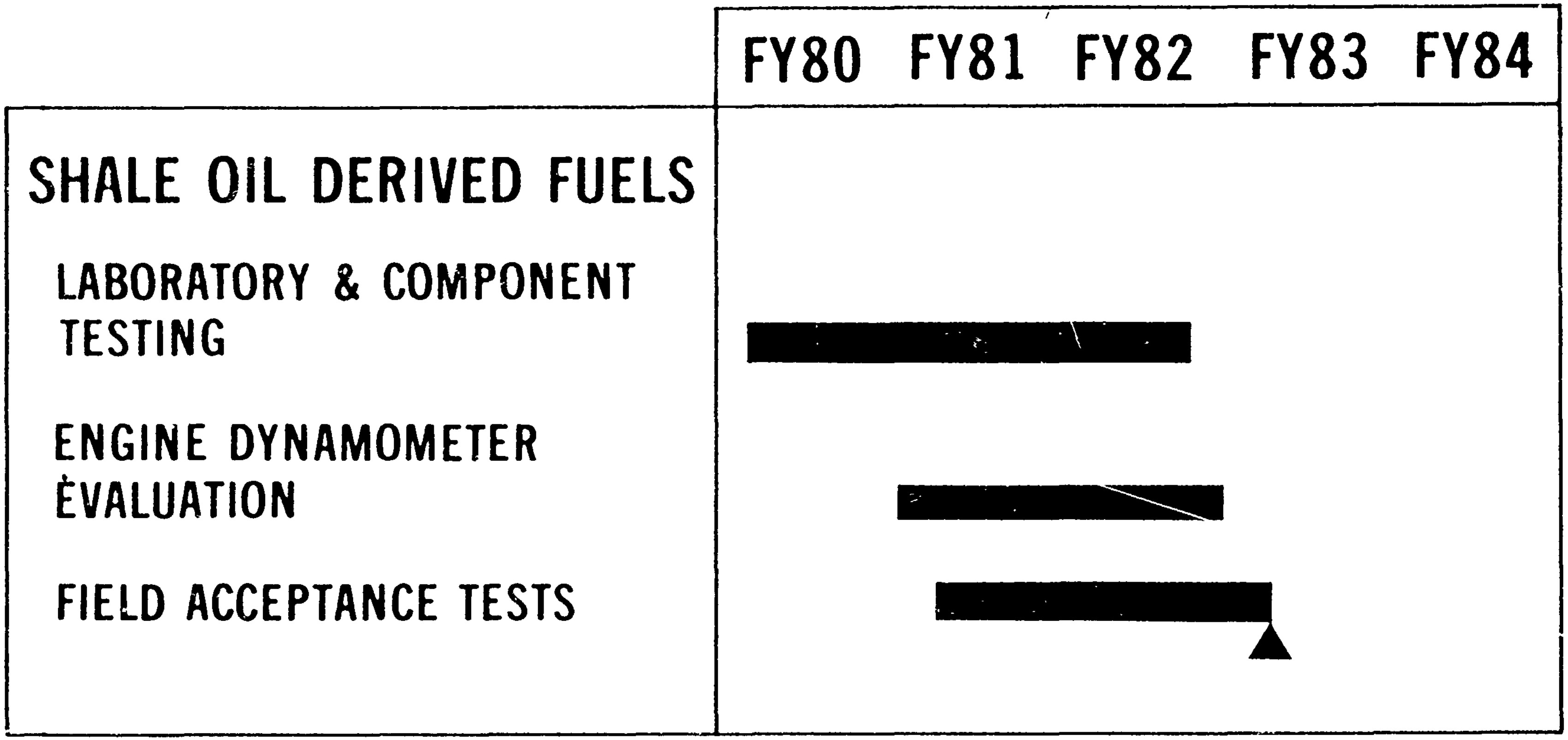
- ENGINE RESPONSIVENESS
  - COMBUSTION QUALITY (CETANE, OCTANE, LUMINOSITY)
  - EMISSIONS
- VOLATILITY & VISCOSITY QUALITIES FOR OPERABILITY
- COMPATIBILITY WITH —
  - METALS & NON-FERROUS MATERIALS
  - ELASTOMERS
  - PLASTICS
- POTENTIAL TOXICOLOGICAL HAZARDS
- MICROBIOLOGICAL SUSCEPTIBILITY
- IMPACT ON RAM-D FACTORS (WEAR TENDENCIES, DEPOSITS, ETC.)
- STORAGE STABILITY
- INTERCHANGEABILITY
- FILTERABILITY AND CLEANLINESS

PROCESS FOR EVALUATING NEW/SYNTHETIC FUELS



PROGRAM TASKS FOR SYNTHETIC FUEL RDTE

PROGRAM TASK	RESPONSIBLE AGENCY
1. LABORATORY CHARACTERIZATION AND SPECIFICATION COMPLIANCE	MERADCOM
2. STABILITY AND ADDITIVE RESPONSIVENESS	MERADCOM
3. COMPONENT AND SINGLE-CYLINDER ENGINE TESTING	MERADCOM
4. TOXICOLOGICAL AND SAFETY ASPECTS	MERADCOM/AEHA/AMBRDL
5. FULL-SCALE MULTI-CYLINDER ENGINE PERFORMANCE AND COMPATIBILITY TESTING	MERADCOM, TARADCOM, AND AVRADCOM
6. FUELS HANDLING AND GROUND SUPPORT EQUIPMENT TESTING	MERADCOM
7. LIMITED FLEET TESTING	MERADCOM, AVRADCOM, TECOM AND TARADCOM



▲ - DEVELOPMENT OF FUEL SPECIFICATIONS FOR MOGAS AND DIESEL

SYNTHETIC/ALTERNATIVE FUELS PROGRAM

OBJECTIVE - EVALUATE EXPERIMENTAL SHALE-DERIVED FUELS TO DEFINE THEIR SUITABILITY IN MILITARY ENGINE SYSTEMS

STATUS: EFFORTS IN PROCESS WITH PARAHOE II FUELS (JP8, JP5, & DFM)

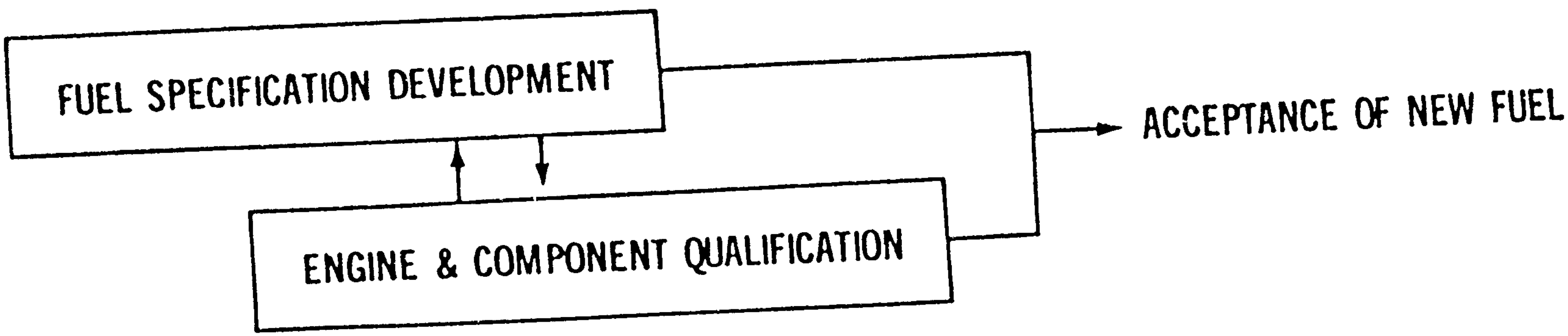
- LABORATORY CHARACTERIZATION AND MATERIAL COMPATABILITY STUDIES
- COMPONENT & COMBUSTOR TESTING (PURDUE UNIVERSITY)
- ENGINE DYNAMOMETER EVALUATIONS
  - ▲ T700 (GE)
  - ▲ T63 (AVCO LYCOMING)
  - ▲ AGT 1500 (AVCO LYCOMING)

ACCELERATED ENGINE FUEL ACCEPTANCE QUALIFICATION METHODOLOGY PROGRAM

OBJECTIVE - DEVELOP NEW METHODOLOGIES THAT REDUCE THE TIME REQUIREMENTS FOR QUALIFICATION OF NEW FUELS WITH EXISTING & NEW ENGINE/ACCESSORY SYSTEMS

TASK: DEVELOP MORE EFFICIENT MILITARY FUEL QUALIFICATION PROCEDURES TO EFFECT CAPACITY TO REACT QUICKLY TO CHANGES ENCOUNTERED IN PETROLEUM REFINING INDUSTRY

CURRENT SYSTEM INVOLVES:



DEVELOP ACCELERATED FUEL QUALIFICATION/SPECIFICATION PROCEDURES

WHY?

- TIME FOR CERTIFYING/VALIDATING ENGINE SYSTEMS ON NEW FUELS OR FUELS ON NEW SYSTEMS TOO LENGTHY
- COSTS FOR CONDUCTING TESTS, LABOR, HARDWARE, & FUEL COSTS
- FUEL CONSERVATION
- NO FLEXIBILITY EXISTS FOR "SHORT-CUTS", I.E., CONVERSION OF JP4 TO JP8
- REFINERY FEEDSTOCKS & PRODUCT SLATES ANTICIPATED TO BECOME MORE VARIABLE

DEVELOP ACCELERATED FUEL QUALIFICATION/SPECIFICATION PROCEDURES

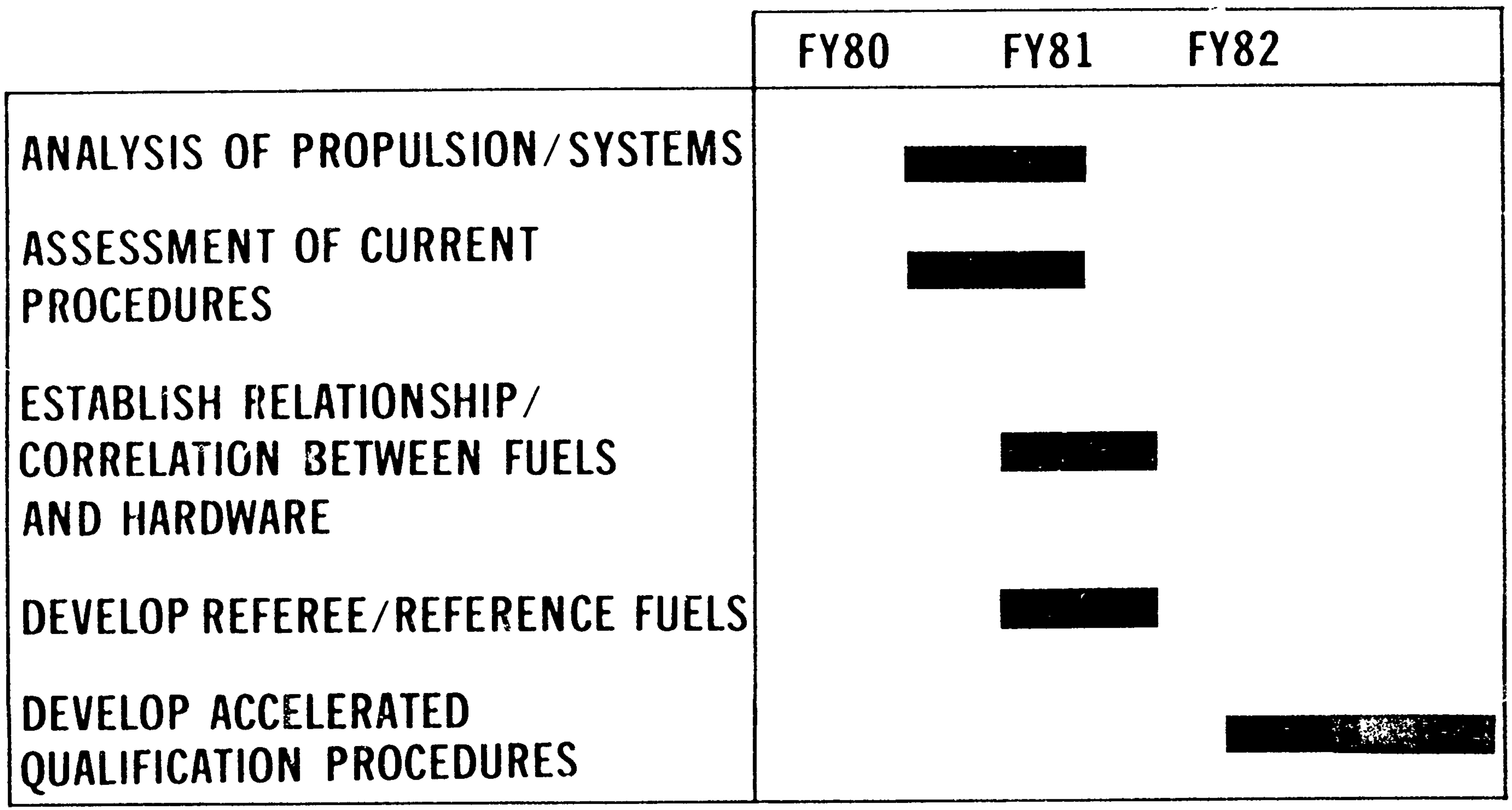
HOW?

- DEVELOP NEW TECHNIQUES FOR CRITICAL FUEL PROPERTIES/CHARACTERISTICS (I.E., HYDROCARBON DISTRIBUTION, LUBRICITY, NON-HYDROCARBON CONSTITUENTS, ETC.)
- DEVELOP ACCELERATED COMPONENT & ENGINE TESTING & EVALUATION PROCEDURES
- DEVELOP REFEREE-TYPE FUELS TO MAXIMIZE "WORST CASE" CONDITION & ACCELERATE TESTING INTERVAL
- INCORPORATE ABOVE WITH COMPUTED MODELLING TECHNIQUES INTO ACCELERATED QUALIFICATION METHODOLOGY
- VALIDATE DEVELOPED SYSTEMS WITH FULL-SCALE ENDURABILITY TEST PROGRAMS

ACCELERATED PROCESS WILL ENCOMPASS THE FOLLOWING

- IDENTIFICATION OF CURRENT PROCEDURES USED FOR ENGINE/SYSTEM
- DEVELOPMENT OF NEW COMPOSITIONAL PROCEDURES FOR SPECIFICATION
- DEVELOPMENT OF ACCELERATED LABORATORY BENCH-SCALE PERFORMANCE TESTS
- CORRELATION OF COMPOSITIONAL & LABORATORY TECHNIQUES WITH EXISTING ENGINE/SYSTEM DYNAMOMETER TESTING
- DEVELOPMENT OF COMPUTER MODELING TO INCORPORATE ABOVE THREE ITEMS
- DEVELOPMENT OF ACCELERATED DYNAMOMETER ENGINE/SYSTEM PROCEDURES TO RAPIDLY PREDICT PERFORMANCE AT HIGH CONFIDENCE LEVEL
- INCORPORATION OF ABOVE DEVELOPMENTS INTO NEW EFFICIENT FUEL-ENGINE QUALIFICATION METHODOLOGY

ACCELERATED FUEL-ENGINE QUALIFICATION PROCEDURE(S) METHODOLOGY



ACCELERATED ENGINE FUEL ACCEPTANCE QUALIFICATION METHODOLOGY PROGRAM

STATUS: EFFORTS IN PROCESS INVOLVE COMPLIATION OF ENGINE AND ACCESSORY SYSTEMS & QUALIFICATION PROCEDURES IN USE

- AVIATION R&D COMMAND (AVRADCOM)
- CONTRACT MODIFICATION TO US NAVY'S PROGRAM (NAVAIR)

MILITARY - INDUSTRY ENERGY SYMPOSIUM
San Antonio, Texas
21 - 23 October 1980

Air Force Quality Control Program

Mr Nick J. Makris
Chief, Quality Division
Directorate of Energy Management

The Air Force Quality Control Program is a subject that I'm extremely pleased to talk to you about today, for it's been a sound program for many years as a lot of you here know.

The Quality Division, which I head, is one of four Divisions within the Directorate of Energy Management. We have total responsibility for the quality of aviation fuel, propellants, gaseous products, chemicals, greases and lubricants used by the Air Force worldwide. Since the primary subject matter of this symposium is aviation fuel, I'll limit my comments just to that area.

Now just a brief word about our Directorate. It is unique in that, personnel wise, we are very small—less than 200 people—and yet we manage in aviation fuels alone over four billion dollars a year. So naturally as managers we put a lot of effort into maintaining the quality of such an expensive commodity—and also keeping in mind a very expensive end item commodity—the aircraft.

For those who don't know, the specifications for turbine fuels are the responsibility of the Aero Propulsion Laboratory at Wright-Patterson AFB, (which incidently are our cohosts at this symposium)—however, our organization has considerable input to these specs. The reason for this is that we have first hand knowledge of what fuel properties will or will not cause problems in either base fuel systems or in aircraft operations. We also have direct responsibility for the technical provisions that are contained in into-plane servicing contracts as well as the documents that cover fuel handling at contractor sites where aircraft are either reworked or built.

The process of assuring the quality of our fuel naturally starts at the refinery—and although the responsibility to accept fuel rests with quality assurance representatives from either the Defense Contract Administration Service or the Defense Fuel Supply Center, we have constant interface with these people since any deviations or waivers from the specification must come through us if the product is destined for Air Force use.

The majority of Government fuel is purchased and accepted at the refinery and delivered to bases using virtually all transportation modes. Multiproduct pipelines into intermediate terminals constitute a major transportation source. Direct delivery from the refinery by tank truck or tank car are of course two very common modes. Other major supply lines involve transportation by barge or by tanker to receiving ports halfway around the world. In most cases, the transport media is interior coated or is made of a nonferrous material—which certainly helps to protect the quality of our fuel.

No job we do is more important than that of directing the on-base quality control program and the procedures that go with this program are included in a technical order maintained by our Division. This document directs inspection, and sampling and testing requirements during receipt, storage and issue of aviation fuels on Air Force bases.

At this point, I would like to emphasize that we do have a fuels testing laboratory at each of the more than 200 Air Force bases worldwide. These laboratories were established at our direction in 1965 when it was evident from repeated contamination problems that we needed more stringent and responsive controls to assure that fuel serviced to aircraft would not compromise the missions. These laboratories are equipped to run the tests shown on the upper left hand side of this slide. As you can see, most of the tests are geared primarily to control physical contaminants that can occur once the fuel is in transit to the base or during handling on the base. This slide also shows where in the system we sample and how often we run the tests. We have a requirement in the Air Force that fuel must have two filtrations prior to entry to the aircraft. The upper portion of this slide depicts a fillstand refueler type system whereas the lower diagram depicts a hydrant system. You can see that we concentrate our sampling downstream from the filter separators. But basically, the fuel is tracked on a day-to-day basis from the time it is received until it is in the aircraft and ready for flight. We have been accused of requiring more tests than necessary--but we strongly believe, and we're backed up by an outstanding reliability record, that our quality program at bases is well worth the effort and money expended.

Some of our base laboratories have more than the typical testing capability to support special situations. Support for the Presidential and Diplomatic Fleet at Andrews AFB is one such case, which goes without saying why this was established. Bases supporting special mission aircraft like our U-2 and SR-71, are also additionally equipped to control contamination of these highly sensitive fuels. We have converted the United Kingdom to JP-8 as many of you know. Consequently, we have had to add flash point testing capabilities at all bases in the UK in addition to basic field level tests. So while we do have some deviations in test capabilities, the important point is—that all base fuel managers have at their disposal a rapid and effective means to control the quality of fuel at any point in their system.

Let's discuss for a minute what type of training is received by the people who run our Quality Program at base level. Naturally, this is a very important part of our QC program. Fuels Management Officers are given a five week course at Chanute AFB in Illinois covering all aspects of fuels management including laboratory training. The laboratory technician course, also held at Chanute AFB, lasts four weeks. Training is intensive, with the officers course limited to 14 students and the laboratory course for technicians restricted to a maximum of 18 students, training in three shifts. This setup assures a high instructor to student ratio for thorough treatment of the subject matter.

An what additional capabilities do we have to support the base fuel laboratories? We staff and manage five area Aerospace Fuel Laboratories located throughout the United States, one in Europe located at RAF Mildenhall AB in the United Kingdom, and one laboratory for support of bases in the Far East—this is located at Kadena AB in Okinawa. All of these sites are equipped to run full specification tests on most all products managed by our Directorate, including of course, aviation fuels. In addition, they are equipped with the latest in instrumentation including NMR, atomic absorption, X-ray, emission spectographs and gas chromatographs.

The five laboratories in the United States are interconnected with our headquarters here in San Antonio by computers. This permits us to effectively monitor and identify quality trends for all products we manage for the Air Force.

Each area laboratory maintains a monthly correlation testing program with base laboratories in their area of responsibility. In addition to keeping track of the testing proficiency of base level technicians, the monthly correlation sample submitted by the base is analyzed by the area laboratory for selected chemical or physical properties most likely to go off spec during movement from the refinery to the base. We use these results to correct problem areas that can occur from improper fuel handling or inadequate systems. The area laboratory can also be used by the fuels officer anytime he suspects a problem may exist with his fuel. This service is also available to all Government quality assurance representatives as well as to other services on request.

Now if these measures and capabilities aren't sufficient to control contamination at our bases, we do have a technical assistance team in my Division whose sole responsibility is to respond to fuel problems that can't be resolved at field level. This team was established in 1964 to serve as the point of contact in the Air Force for commands to seek help whenever their bases experience fuel problems. It's a small group of engineers and quality people, headed by a military chief, who have had many years of experience in troubleshooting a wide variety of fuel quality and systems problems. Operating strictly on request, the team can be on their way to anywhere in the world in less than 24 hours. Not all of their time is spent on the road, however—this team has done most of the work in planning and arranging this Symposium.

Up to now I've talked primarily about testing capability at the base and what our area laboratories do—but we do have other areas which tie in directly with our Quality Control Program. System design is, of course, a major factor in maintaining a quality product. For several years it has been a requirement in the Air Force that all new aviation fuel systems either be internally coated or constructed of nonferrous materials. Bulk tanks are required to have inverted cone bottoms, center sump drains for efficient water removal and product recovery systems to save product and prevent ground pollution. Aboveground tanks must be cone roof with floating pans—and of course this design prevents external contaminants from entering the tank and keeps vapor losses to a minimum. We are also making tremendous strides in coating existing bulk tanks when they are due for cleaning. In addition to these storage systems, more pressurized, demand type, hydrant systems for both conventional and hot refueling are being built with quality in mind.

And last I want to say something about another area that has had a positive effect on our Quality Program—and that is the American Petroleum Institute Trophy. In 1966 this Directorate in conjunction with the API established a program where the best base fuels operation in the Air Force would be recognized by receiving this trophy.

As you might expect, competition for this coveted award has been fierce each year and has been extremely valuable in giving base personnel and commands the incentive to excel. Command nominees are evaluated by representatives from the Air Staff in Washington and our technical assistance team. Major Ruchalski, our current team chief, will be leaving in a few days to evaluate this year's AFB finalists, Eglin, FL; MacDill, FL; Minot, ND; and Torrejon AB in Spain. Last year, McConnell AFB in Kansas was the winner and for three consecutive years prior to that, Hickam AFB out in Hawaii won the competition.

In closing, our job, just like almost everyone else in this business hasn't been made any easier by the energy crutch that started hitting us hard in 1973. The shortages and accompanying increased cost of turbine fuel have forced us to give even more attention to quality and to critically evaluate the impact of using fuels which may possess properties of lesser quality than we have today. However, I'm confident whatever the characteristics of fuel we decide on or are forced to use in the future, we, in the Air Force will continue to have a sound, effective Quality Program to insure the best and cleanest fuel available is delivered to our aircraft.

REPORT ON GROUNDING

DIFFERENCES IN PHILOSOPHY AND PRACTICES

BY

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ELECTROMAGNETICS BRANCH

NAVAL AIR SYSTEMS COMMAND

PRESENTED AT

THE 1980 INDUSTRY-MILITARY ENERGY SYMPOSIUM

ABSTRACT

Significant conflicts and appreciable confusion within the military and industry over what constitutes proper electrical grounding requirements have been plaguing all involved with aviation. In addition, numerous questions have been raised in the Navy as to whether or not documented requirements are cost effective and/or safe. Naval Air Systems Command has initiated a program to assess the present practices and the basic requirements for electrical grounding of an airframe during various service operations. To support this effort, working groups were established which achieved several major milestones. They accumulated considerable data by performing documentation searches, field surveys, and tests. The field surveys provided electrical characteristics of grounding facilities at a number of bases throughout the United States and Europe and at sea. In addition, the pertinent electrical characteristics of airframes have been measured. While the program has not been completed as of this date, the outcome will be the basis for providing requirements for future Navy policy.

My discussion will pertain to the data thus far obtained for the information of the participants in the 1980 Industry-Military Energy Symposium.

1.0. INTRODUCTION

To prevent electrical shock and static discharge hazards and detrimental electromagnetic environmental effects (E^3), electrical grounding and bonding has been mandated for various aircraft ground operations. The number and complexity of operations performed and the variety of effects possible at sea and at shore facilities has however, resulted in confusion in electrical grounding procedures. A cursory survey intimated that:

(1) conflicts exists in specifications and standards.
(2) potentially hazardous conditions may exist while following one or more published guidelines.
(3) confusion exists in the fleet.
(4) techniques and procedures and facilities may vary widely.
(5) some techniques and procedures may be neither technically effective nor cost effective.

The Naval Air Systems Command has initiated an Airframe Electrical Grounding Requirements Program whose goal is to provide a technically substantiated, well documented electrical grounding philosophy for aerospace applications. The program's findings will be used to resolve existing conflicts, recognizing necessary deviation or waivers and standardizing electrical grounding techniques, evaluation methods and documents. The program results will provide a concise and accurate input for development program planning; thus, hopefully assuring proper electrical grounding specifications in the initial design stages of new systems.

Two terms are frequently used in this report and for the purpose of clarity are defined as follows:

Bonding - is an intentional electrical connection, which provides a low impedance path, between two structures (aircraft, truck, tank, building, equipment, etc.) or between joints of a structure.

Grounding - is the attachment of an intentional electrical conductor, which provides a low impedance path, between a structure (aircraft, truck, tank, building, equipment, etc.) and earth.

2.0 SOME PROBLEM AREAS

The items listed below provide an indication of some of the problem areas and different approaches taken with grounding of aircraft.

(1) U. S. air carriers electrically ground aircraft in the U. S. and in Europe. However, foreign carriers in Europe do not attach ground cable during fueling but mandates grounding in hangars.

(2) Hardware and requirement difference exist among the military services and with NATO.

(3) Air Standardization Agreements have been signed to ensure that member nations can interconnect aircraft and ground support equipment of their member nations to ensure safety to personnel and equipment. They specify, among other things, that refuelers are to be bonded to aircraft and to earth. In the U.S. Navy, however, an instruction relaxes this requirement.

(4) Differences exist among Naval Air Stations - in aircraft grounding procedures.

(5) Military Standards contain requirements for ground cables and prohibits use of alligator clips. However, publications for aircraft specify use of tiedown chains as prefered method of grounding but alligator clips are depicted in photographs in all Maintenance Instructions.

(6) Reports from the fleet identify personnel receiving electrical shocks when touching aircraft surface during maintenance turnup.

(7) Reports from Rework Facilities point out lack of adequate ground points on aircraft provide potential for serious damage and hazard to personnel in addition to preventing proper compliance with OSH requirements.

(8) Various suggestions for improvements of grounding hardware from the fleet, identify unfamiliarity with prescribed standards.

3.0. PROGRAM EFFORT

Technical assistance has been obtained from a number of activities which are listed in Figure 1. In addition, an engineering working group was formed of personnel from pertinent activities. The working group has accumulated considerable data by performing documentation searches, field surveys and tests on aircraft The work breakdown structure (WBS) of the program, task definitions and scheduling aggregated to form a program road map. The WBS outline is shown in Figure 2.

3.1. Documentation Surveys

Documentation Surveys of Government requirements and technical literature, identified the present requirements of various authorities regulating aircraft operation. A considerable variation in requirements, techniques, and rationale was found. Two major areas of concern noted were:

a. The establishment of proper maximum and/or minimum values for impedance from grounding point to earth with the selection of an adequate measuring technique to verify them.

b. The question of bonding between fueling device and aircraft during fueling versus bonding plus grounding.

ENGINEERING TECHNICAL ASSISTANCE

Naval Air Systems Command

Naval Air Engineering Center

Naval Air Development Center

Naval Air Test Center

Naval Surface Weapons Center/Dahlgren, Va.

Naval Sea Systems Command

Naval Electronic Command

Naval Facilities Engineering Command

Commander Naval Air Atlantic Fleet

Naval Research Laboratory

Dayton T. Brown Laboratory (EMC Section)

AirForce Systems Division

Lightning and Transient Research Institute

Lightning Technology Inc.

FIGURE 1

Work Breakdown Structure
for the
Airframe Electrical Grounding
Requirements Program

- Management
  - Program Plan
  - Program Control
- Aircraft Grounding Requirements Literature Survey
  - Navy Instructions
  - Navy Regulations
  - Aircraft Technical Manuals
  - Safety Standards
  - NAVOPS, NAVMAT Directives and Publications
  - Incident Reports
- Technical Literature Survey
  - Technical Papers
  - Test Reports
  - Position Papers
- Field/Equipment Survey
  - Survey Plan
  - NATC Pax River, MD
  - MCAS Cherry Pt., NC
  - NAS Pensacola, FL
  - NAS Brunswick, ME
  - MCAS Yuma, AZ
  - NAS Miramar, CA
  - NAS Whidbey Is., WA
  - Richards-Gebaur AFB, MO
  - Kelly AFB, TX
  - NAS ADAK, AK
  - NAS Barbers Pt., HI
  - NAS MIdway
  - NATO Facilities
  - Carrier Operations
- R&D Survey
  - Exxon Corp.
  - Shell Research Ltd.
  - NRL
  - NBS
  - Aviation Industry
- Liaison
  - Air Force
  - Army
  - NATO
  - ASCC
- Evaluation
  - Grounding Requirements Literature
  - Technical Literature
  - Field
  - R&D
  - Liaison
- Reports
  - Monthly Reports or Working Group Meetings
  - Trip Reports
  - Interim Data Reports
  - Final Report

FIGURE 2

3.2. U.S. Field Surveys

U.S. Field Surveys were initiated to establish a source of data which the working group had personally participated in fact gathering. Two survey teams were established to gather data within schedule constraints. To obtain maximum diversity within a limited sample, sites were selected by consideration of extremes in climate, geological characteristics and operational parameters. The survey determined both the physical condition and configuration of the grounding systems at thirteen military facilities and observed various aircraft service evolutions as they are normally performed by base personnel. The stations surveyed as part of the Airframe Electrical Grounding Requirements Program were as follows:

NAS Brunswick, Maine
NAS Miramar, California
NAS Pensacola, Florida
MCAS Yuma, Arizona
NAS Barbers Pt., Hawaii
NAEC, New Jersey
Kelly AFB, Texas
MCAS Cherry Point, North Carolina
NAS Patuxent River, Maryland
NAS Whidbey Island, Washingtion
NAS Adak, Alaska
NAS Midway Island
Richard-Gebaur AFB, Missouri

3.2.1. Electrical Impedance

Electrical Impedance to earth measurements were performed by the teams. The electrical impedance value from a designated grounding point to the earth is one of the basic design parameters often questioned due to the effects of corrosion and other time dependent processes.

The impendance must be low enough to allow energy transfer from the aircraft to the earth quickly without producing damaging power levels in the grounding system. Measurements were made with the Biddle Null Balance Earth Testers Model Number 63241 and Meggers Biddle Model Number 21159.

Procedures recommended by the equipment manufacturer were found to provide consistent results and close agreement when compared with the various test equipments supplied through local public works groups. In all cases where stakes could be driven in the earth, the three point, fall of potential, measurement method was used. Where the ground point location prohibited lccess to open earth, the two point method referencing building or power system ground was used. Several comparisons of the two methods were made and agreement between methods was found to be acceptable.

3.2.2. Aircraft Characteristics

The second major source of new data in the program was Aircraft Characteristics. This measurement program was undertaken on the basis that a primary factor in the evaluation of grounding philosophies, techniques, and parameters is the electrical characteristics of the system to be grounded. The program teams performed a series of tests to determine these characteristics on a variety of airframes over a variety of ground planes. The tests provided:

a. Measurements of the airframe capacitance to ground with the airframe electrically isolated from ground (ability to accumulate charge).

b. Measurement of airframe resistance to ground through tires (ability to dissipate charge).

c. Measurement of charge accumulation during engine runup (low engine power only) (possible source of charge buildup).

d. Measurement of static voltages and current flow in various bonding and grounding conductors during fueling (another possible source of charge buildup).

3.2.3. Eastern U. S. Field Observations

General observations noted at NATC, MCAS Cherry Point, NAS Pensacola, NAS Brunswick and Richard-Gebaur AFB by the eastern survey team were as follows:

. Of approximately 20 truck fueling operations, none were performed without grounding the truck, bonding the aircraft to the truck, and, in some cases, grounding the aircraft via its own ground cable.

. In several cases, ground lead clips were connected to painted surfaces. In many cases, clip leads were used although phone jack (ground) connectors were available on the aircraft. Standardization is not apparent.

. Aircraft in hangars are generally grounded. Those in outside parking areas are generally only grounded for maintenance operations.

. Fueling - Where larger aircraft are involved, C-130 and P-3, fueling is via truck. For smaller aircraft both truck or Hot Refueling Stations may be used. In either case, there were grounds applied to the system.

. Power - Where large aircraft are involved, APU or power carts were used on the parking aprons. Smaller aircraft used service consoles (when available). The consoles incorporate an earth ground.

. In most observed maintenance situations inside the hangar, utility (house) power was used.

. In many maintenance operations, power tools, light extentions, and other maintenance equipment externally connected to the utility 115V/60 Hz system were used aboard the aircraft.

. Grounding straps were not generally effective on aircraft, but might be if aircraft impedance is very high as at Yuma.

. Several comparisons were made with Public Work's grounding impedance instruments, and results were in agreement in all cases.

. Megger measurements of aircraft resistance were linear over a five-step range from 100V to 1000V.

3.2.4. Western U. S. Field Survey Observations

General observations noted at MCAS Yuma, NAS Miramar, NAS Whidbey Island, Kelly AFB, NAVSTA ADAK, NAS Barbers Point and NAS Midway Island by the western survey team were as follows:

. Most crews at NAS Miramar use tie down points as grounds. No formal instruction is given to crews with regard to grounding of aircraft at the Air Station.

Not all ground points are marked. Covers in one area could not be removed due to the fact they were sealed over with a layer of apron sealer.

Most aircraft are hot refueled at NAS Miramar. Aircraft are bonded to the fuel line, which in turn is grounded. Aircraft are not directly grounded during the refueling process.

. Tire resistance appears to be extremely high on sampled A-4 at MCAS Yuma. Readings of other aircraft are high, but not as high as the referenced A-4.

Fueling trucks use the 2 point (Y) method of grounding and bonding, one clip connects to ground and one clip to the aircraft. The cables and clips on the trucks are periodically inspected. New drivers in Yuma receive 80 hours of training, of which 40 hours are for observing and 40 hours for operation under supervision. Fuel truck driver connects grounds to "earth" and to aircraft. The aircrew then attaches the fuel hose to aircraft, and gives the driver a signal to start the pumps. Upon completion of refueling the aircrew removes the hose and the fuel truck driver removes the grounds.

. Measurements of the bonding and grounding quality of the refueling area are performed periodically except at NAS ADAK. Bond jumpers are visually checked daily.

Ground points at NAF ADAK are not used during the winter months due to the fact that snow covers the area most of the time. They may be used during the summer months, but usually they are not in order to avoid confusion among the refueling personnel. On occasion, a tie down may be used as a ground point.

When defueling at NAF ADAK a tie down point is used as a ground if the ground point cannot be located.

During thunder and lightning storm activities, no refueling of aircraft, nor handling of stores is carried out unless the storm is 10 to 15 miles away or more.

At ADAK the primary area was not used because it would not take the weight of present aircraft. Secondary area is used at time of survey. Both areas were under approximately 3 inches of ice, slush and water. Extremely high winds were also encountered. No measurements were made due to these conditions. A long wire was imbedded in the ground and tied to a ground stake. Since the area was basically under water, we would have been effectively measuring the resistance of the water-slush-ice combination.

No hot refueling is performed at NAF ADAK.

. NAS Whidbey Public Works identified that poor soil conditions made it difficult to reach a good ground. Soil is peat bog and hard pan. This base has approximately 2300 tie down and ground points. All fueling is performed by truck whether normal or hot at NAS Whidbey. Refueling performed by contractor uses three-point method. Fueling inspector checks equipment every day. It is officially checked once per month. The safety officer is writing a memo not to ground aircraft, just bond during refueling.

Grounding of aircraft and of weapons depend upon the particular types of weapons being loaded.

The grounds in the red label area are not sufficient nor are they in the proper location for particular aircraft.

Ground points at NAS Whidbey are tested once per year, except for red label areas where they are checked twice per year. In one area tie downs are designed to be used as grounds. The tie downs are all welded to steel in the concrete, then tied to ground points driven into the ground. A stainless steel bead is welded across the top of each tie down to insure good electrical contact with grounding clips.

. All grounds on aprons at Kelly AFB were also tie downs. All grounds on aprons were marked and dated. In hangars the recessed ball type is used.

. All grounds are marked in yellow at Barbers Point Naval Air Station. A few tie downs were outlined with a red and these areas were measured and found to have a resistance of 2390ohms. Apron area is concrete on a coral base.

Two Marine C-130 aircraft were parked next to each other on the ramp - one was grounded, the other was not.

Navy personnel handle the fuel trucks and aircraft fueling.

Witnessed the fueling of an A-4, both truck and aircraft were grounded.

Mechanical grounds are checked monthly.

. Tie downs appear to be constructed from stainless steel (non-magnetic) at Midway Island Naval Air Facility. The apron is divided into sections, alternate areas of asphalt coated then concrete. There are no grounding points on the ramp area. The hangar area is concrete.

During normal refueling of aircraft both aircraft and refueling trucks are grounded (three point method).

During a rare hot refueling, the truck is bonded to aircraft only.

Fuel truck drivers are Navy personnel-trained for 6 weeks.

Thunderstorms occur mainly during the winter season. There have been eight in the last 4 months. All fueling activities are shut down during thunderstorms.

Refueling trucks are fairly new, ground wires are visually checked on a daily basis.

3.3. Shipboard Survey

Insight into shipboard facilities, shipboard operating and maintenance procedures relative to airframe grounding necessitated the initiation of an electrical grounding survey during Fleet operation. Data was obtained during the survey while aboard the Navy Aircraft Carrier USS Dwight D. Eisenhower, CVN69. The survey was specifically not intended to be a formal quality assurance evaluation nor a maintenance effort identifying faulty grounds requiring rework. The data gathered, however, are of a sufficiently random nature and are extensive enough to provide an overview of the similarities and differences in electrical grounding practices relative to Air Force and Naval land bases.

3.3.1. Measurement Summary

The survey team performed a series of tests to determine airframe and ship characteristics. These tests provided:

a. Measurements of various ships structure such as catapult shuttle to flight deck, elevators to flight deck verified ground impedances between elements to be less than 10 milliohms.

b. Aircraft bonding of structure especially from weapon racks to main airframe measured generally in the order of milliohms.

c. The integrity of ship's power conductor was measured by comparison of the aircraft impedance to ship structure with an without external power cable connected. Where aircraft impedance to ship structure was high without external power, the connection of the power cable provided a ground path of 0.5 ohm or less.

3.4. Surveys of European Installations

Surveys of European Installations were initiated to provide insight into operating and maintenance procedures and facilities capability relative to requirements for airframe grounding. The facilities surveyed were as follows:

- RAE London, England
- Snell-Thornton Research Center, Chester, England
- Valkenburg, NAS, Netherlands
- MOD, Bonn, Germany
- Neuberg AFB, Germany
- BWB, Munich, Germany
- Rien Airport, Munich, Germany
- Gioia Del Colle AFB, Italy

3.4.1. Measurement Procedures

Test procedures and equipment utilized by the survey team at these facilities were identical to those used in the U. S. field survey.

3.4.2. Royal Aircraft Establishment Observations

General observations noted of the Royal Aircraft Establishment (RAE) London, England were as follows:

. The RAE noted that grounding rationale and procedures are not clearly defined for the British Military Aviation.

. The RAE has tasked the Central Servicing Development Establishment (CSDE) with the review and recommendations for revision to present grounding documentation. The task was initiated December 1979 and is due for completion December 1980. However, the present practices employed are to ground aircraft during each service operation.

. The RAF has issued a requirement for all aircraft to be earthed during fueling. Since this resulted in a hardship on small trainer aircraft, a waiver has been granted in this area if no power greater than 28VDC is applied during the fueling process.

. Aircraft, Dolly and Store are required to be grounded during stores loading and unloading.

. The preferred grounding method is via a stud and wingnut on the aircraft which secures an eye-type connector on the cable end. Jack and plug are also generally available for conformance with NATO Standard Agreement (STANAG) requirements but are not a preferred method.

. The conductive additives are used by the RAF and civilian aircraft. No recheck of fuel conductivity level is made after distributing treated fuel from main depots.

. The CSDE has also been tasked with related grounding problems such as defining temporary ground spike impedance and resolving problems with splitter box ground loops.

3.4.3. Shell Thorton Research Center Observations

General observations noted at Shell-Thornton Research Center (TRC) Chester, England were as follows:

. Shell recommends aircraft grounding, and feels that it is being done in all areas where Shell is operating. Mr. John Mills, Shell's fuel hazards expert, does not agree. He considers bonding sufficient but limits comments to fuel static charge only.

. The British Standards Institute committee in formulating the "Code of Practice for Stati. Electricity" has now a requirement to ground aircraft during refueling.

. The conductive additive does not remove the need for grounding.

. Shell disagrees that a reduced amount of conductive additive is more hazardous than none. Up to some given point (250 ps), the effectivity of the additive is directly proportional to the quantity present.

. Shell disagrees that there is a time dependance for the effectivity.

. Shell states that there has been no report of component failure due to the additive in 15 years.

. There has been no indication of hyperactivity in fuel after analysis of fuels from accidents.

. ASA 3 and Stadus 450 (Dupont Product) is now cleared for use by USAF.

. Flash point is not the final criteria in determining safe operation. Potential for ignition exists at lower temperatures, especially with foaming fuel.

. Shell stated that use of the conductive additive will prevent electrostatic sparking during fueling with red foam in tank. However, the additive (even when used in maximum quantities) will not eliminate all sparking where blue foam is present.

3.4.4. Valkenberg NAS Observations

General observations noted at Valkenberg Royal Navy Air Station, Netherlands were as follows:

. Aircraft are grounded during each servicing operation.

. Airframe are grounded during refueling operations and bonded to fuel trucks by a separate bonding cable and wire in the hose. Fuel truck is also grounded.

. No reports of hazard to equipment or personnel due to electric power, static electricity or lightning over the last several years was found.

. Fuel hose wire is checked each 4 weeks for a resistance of less than 0.1 ohms/meter/.

. Static drag straps are mounted near the wheels on both P-2 and SP-13A, to provide static discharge to ground.

. Fuel hose and ground wire have both clips and phone jack plugs.

. Fuel rate for P-2 aircraft was approximately 400 L/min.

. P-2 uses fuel F-22, SP-13 uses fuel F-35.

. Fuel rate for SP-13 approximately 910 L/M. (two sides simultaneously).

. No radar transmission is permitted within 25 meters during fueling.

. In general, ground planes on aprons were established within the last two years. Grounding is accomplished via separate ground rods, rather than a wire grid.

. Hangar grounds marked as last tested in 1975 were tested and results verify grounds are still satisfactory.

. Aircraft carry their own ground wire.

. Shipboard tiedown uses wire cables rather than chains.

3.4.5. Ministry of Defense (MOD) Bonn Observations

General observations noted at the Ministry of Defense, Bonn, Germany were as follows:

. German Air Force and Navy both use a 2 point ground configuration during fueling.

. No conductive additives are presently required but these additives are considered desirable and it is expected that they will be required in the near future (2 years).

. Further studies of grounding requirements are in progress.

. While several attempts have been made, no evidence of hyperactive fuel has been found.

. To maintain availability of ground point in snow, the ground rod is extended approximately 0.5 meter above ground. If a problem still exists during poor weather conditions, minimum requirements are to provide only a fuel truck to aircraft bond.

. The Scientific Institute, an organization which provides consulation services to the MOD, disagrees with the official MOD requirement for bonding and grounding of aircraft during fueling. Their position is that only bonding is essential during fueling in Germany, and that aircraft grounding "in Germany" is not necessary due to low tire resistance and high soil conductivity This view, however, was based only on fuel transfer characteristics.

3.4.6. BWB and Neuberg AFB Observations

. General observations noted at Bundesant fur Wehrtechnik und Beschaffung (BWB) Munich, Germany and Neuberg Air Force Base were as follows:

. German officials of BWB in Munich maintained that grounding of aircraft was absolutely necessary for all servicing operations and including while aircraft are parked. Their position was; better standards should be enacted for aircraft grounding, covering aircraft receptacles and types of wires used by the host country. They favor using the French designed aircraft ground receptacle which is very rugged, provides prositive retention and will handle fault currents.

. Neuberg Air Base measurements of earth grounds and aircraft grounds were low and similar to those obtained in the United States. Electrical measurements of aircraft tires were obtained. In refueling areas outside shelters, values of high megohm resistance were recorded between airframe and ground when purposely ungrounded for measurement.

3.4.7 Rien Airport Observations

General observations noted at Rien Airport, Munich, Germany were as follows:

. The facility contains under apron fuel storage tank and pumper trucks which are used to extract the fuel and feed fuel to the aircraft during refuelings. Refueling operations were observed and measurements were made on ground and aircraft. During refueling, the pumper was bonded to the aircraft but not to the remainder of the underground system. Luxthansa hangar facilities were visited and all aircraft were noted grounded.

3.4.8. Gioia Del Colle AFB Observations

. General observations noted at Gioia Del Colle Air Force Base were as follows:

. Aircraft generally were found grounded even when parked. However, two aircraft were observed not grounded while parked. No service operations were in progress. Fueling operations of these aircraft (ungrounded) while on the apron were as follows:

a. The truck was grounded

b. The truck was then bonded to aircraft

c. The fuel operation was then started

Note: No additional grounding connection was made from aircraft to earth. After refueling was disconnected, aircraft impedance to earth was measured and found to be 15K with no aircraft to earth connections other than the tires.

. Shelters were utilized and aircraft in shelters are grounded during all operations. In the shelters the triangle method for grounding and bonding is used during refueling. No requirement was found for fuel conductive additives. Special hardware, found nowhere else, exists here for switching grounds. Hardware of switch boxes and ground plugs are designed to be explosion proof (i.e. any arching would be contained in the switch enclosures rather than at aircraft or truck).

. Static ground to earth measurements were made at various shelters, hangars and aprons. These measurements were found to agree very closely with routine measurements made by base personnel. All values measured in this sample were adequate for static grounding.

. The aircraft ground receptacle accepts a straight banana plug with no indent. Some plugs had an indent. Some plugs were also noted of slightly larger diameter, possibly tapered, that jammed into the receptacle for about 1 inch depth. No retention system for the tapered or the straight barrel plug was apparent. It was noted the Italian F-104S aircraft receptacle was of different design. It appears to be more rugged and simpler although it may not be as secure as the French design observed in Germany.

. Noted that hardware is well maintained.

3.5. Survey Naval Bases

Other than the naval station and facilities, personally visited by the survey teams, twenty-two naval facilities identified by mail what practices are employed relative to aircraft grounding. Twenty-two identified that grounding is implemented at all times for maintenance and ordnance operations. In addition, all facilities bond fueler to aircraft and eighteen ground aircraft while fueling. Four facilities identified that only bonding was implemented during refueling. All stations identified use of more than two fuels, of which 100% use JP5 and 66% use JP4. No conductive additive is presently used.

4.0. SUMMARY OF SURVEY DATA

4.1. Measurement Data

Measurement data contained in the following tables summarize the values recorded for each test condition at each specified test site. Due to the nature of the test sites, equal number of test points were not recorded at each site. Data recorded are samples of ohmic values and does not provide the absolute maximum and minimum values existing. It provides, however, a fairly accurate indication of an average of values and variations present. The data are presented as follows:

TABLE	
I	Resistance of Aircraft to Ground
II	Resistance of Grounding Points - for Hangars

5. CONCLUSIONS

While the program, as stated previously, is not completed at this time, it is clear from the data sampling that:

. Documentation must be corrected to preclude the present confusion in electrical grounding of aircraft. In addition, a single document is required that provides policy, guidance and direction for all service evolution.

. Considerable cost savings can be accomplished by using mooring points for static earth grounds.

. Aircraft tire resistance or tiedown chains cannot be relied upon to provide adequate conductivity to ground. Positive ground connections using wire cables are required to assure safety to personnel and aircraft.

TABLE I

RESISTANCE OF AIRCRAFT TO GROUND - NO GROUND CABLE ATTACHED

Location	Minimum (OHMS)	Maximum (OHMS)
CONUS		
NATC, Patuxent River, Maryland	-	-
MCAS, Cherry Point, North Carolina	15K	200K
NAS, Pensacola, Florida	100K	1 meg
NAS, Brunswick, Maine	30K	160K
MCAS, Yuma, Arizona	9 meg	40 meg
NAS, Miramar, California	17K	1 meg
NAS, Whidbey Island, Washington	2K	20K
Richards-Gebour AFB, Missouri	10 meg	15 Meg
Kelly AFB, Texas	1K (in rain)	27K
Range	1K	40 Meg
Non-CONUS		
NAVSTA ADAK, Alaska	4K	4K
	Only one aircraft tested.	
NAS Barbers Point, Hawaii	4K	20K
NAF Midway Island	No aircraft available for test.	
Range	4K	20K

TABLE II

RESISTANCE OF GROUNDING POINTS - IN HANGARS

Location		Minimum (OHMS)	Maximum (OHMS)
CONUS			
NATC, Patuxent River, Maryland		5.60	6.90
MCAS, Cherry Point, North Carolina		0.19	0.37
NAS, Pensacola, Florida		0.40	10.30
NAS, Brunswick, Maine		167.0	1450.0
MCAS, Yuma, Arizona		0.17	0.59
NAS, Miramar, California		0.30	0.63
NAS, Whidbey Island, Washington		0.25	9.30
Richard-Gebour AFB, Missouri		0.19	0.19
Kelly AFB Texas		0.74	0.74
Range		0.17	1450.0
Non-CONUS			
NAVSTA ADAK, Alaska		0.81	.81
NAS Barbers Point, Hawaii	Old Hangers	5.2	637
	New Hangers	0.71	2.7
NAF Midway Island		0.41	83.4
Range		0.41	637

TABLE III

RESISTANCE OF AIRCRAFT MOORING POINTS

Location	Minimum (OHMS)	Maximum(OHMS)
CONUS		
NATC, Patuxent River, Maryland	36.0	230.0
MCAS, Cherry Point, North Carolina	750.0	750.0
NAS, Pensacola, Florida	191.0	288.0
NAS, Brunswick, Maine	*	*
MCAS, Yuma, Arizona	160.0	289.0
NAS, Miramar, California	78.0	940.0
NAS, Whidbey Island, Washington	166.0	447.0
Richard-Gebour AFB, Missouri	21.3**	63.5**
Kelly AFB, Texas	7.7**	32.9**
Range	36.0	940.0
Non-CONUS		
NAVSTA ADAK, Alaska	0.88	690
NAS Barbers Point, Hawaii	0.41	595
NAF Midway Island	0.47	298
Range	0.41	690

*Local Instructions require uses of grounding point rather than tie down for all grounding operations.

**The same facility as in Table IV.

TABLE IV

RESISTANCE OF GROUNDING POINTS - OUTSIDE

Location	Minimum (OHMS)	Maximum (OHMS)
CONUS		
NATC, Patuxent River, Maryland	1.6	22.2
MCAS, Cherry Point, North Carolina	1.0	88.8
NAS, Pensacola, Florida	1.55	54.5
NAS, Brunswick, Maine	3.0	58.0
MCAS, Yuma, Arizona	3.6	32.6
NAS, Miramar, California	0.89	286.0
NAS, Whidbey Island, Washington	0.39	30.6
Richards-Gebaur AFB , Missouri	21.3	63.5
Kelly AFB, Texas	7.7	32.9
Range	0.39	286.0
Non-CONUS		
NAVSTA ADAK, Alaska	0.60	1.3
NAS Barbers Point, Hawaii	0.47	224.0
NAF Midway Island	0.39	740.0
Range	0.39	740.0

TABLE V

SUMMARY OF SPECIFIC AIRFRAME ELECTRICAL CHARACTERISTICS

DATA SUMMARY OF PARAMETER EXTREMES

	Minimum	Maximum
Aircraft Resistance Measurements	5K	20M
Aircraft Capacitance Measurements	1.5nf	5.1nf

STATIC VOLTAGE DURING FUELING TA-4

Voltage Measured	Remarks
+600V. to - 600V.	Positive to negative varied with a period of about 1 second at 60 gpm fuel rate; 0.5 second at 120 gpm fuel rate.
-2500V.	Removed ground after refueling and waited approximately 2 minutes before reading. TA-4 was isolated by acrylic sheets under wheels.

DC CURRENT MEASUREMENTS DURING TA-4 FUELING

	60 gpm	120 gpm
current on Bonding Wire	0.8ua	1.4ua
current on Ground Wire	0	0

TABLE VI

DATA SUMMARY - CARRIER (CVN-69)

A - No tiedown chains on aircraft

Aircraft Type	Impedance (OHMS) Min.	Max.
A-7E	80K	5M
EA-6	0.6M	3M
A-6E	.04M	4M
KA-6D	1M	1M
S-3A	15K	1M
F-14	0.4M	100M
B - with tiedown chains attached		
A7E	0.7	700
S3A	0.4	20
KA-6D	1.8	970
EA-6B	5.0	500
F-14	0.5	40K
A-6E	0.3	800
SH-3H	800	2K

NOTE: Tiedown chains removed from aircraft and resistance measured:

(1) Full Length - 5 Megohm (Using 1000V Megger)
(2) 10 Links 4 Megohm.

TABLE VII

DATA SUMMARY OF NATO BASES

RESISTANCE OF GROUNDING POINTS (OUTSIDE)

Location	Minimum (OHMS)	Maximum (OHMS)
Valkenberg, NAS	1.0	7.7
Neuberg, AFB	0.7	10
Gioia Del Colle, AFB	0.7	2350

RESISTANCE OF GROUNDING POINTS (HANGAR)

Location	Minimum (OHMS)	Maximum (OHMS)
Valkenberg, NAS	5.1	9.0
Neuberg, AFB	0.7	10
Gioia Del Colle, AFB	0.60	1.4

RESISTANCE OF AIRCRAFT MOORING POINTS

Location	Minimum (OHMS)	Maximum (OHMS)
Valkenberg, NAS	124	350
Neuberg, AFB		
Gioia Del Colle, AFB	648	2380

RESISTANCE OF AIRCRAFT TO GROUND

Location	Minimum (OHMS)	Maximum (OHMS)
Valkenberg, NAS	4.4K	100K
Neuberg, AFB	15K	40 Meg
Gioia Del Colle, AFB	15K	400K

CANADIAN EXPERIENCE WITH CONDUCTIVITY ADDITIVES

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1. INTRODUCTION

The Royal Canadian Air Force (RCAF), as the Air Element of Canadian Forces was known at that time, was the first aircraft operator to fly with turbine fuel containing static dissipator additive. Canadian aviation fuel specifications were the first to include a mandatory requirement for an electrical conductivity increasing additive. Experience in Canada with static dissipator additive - Shell ASA-3 - extends back to the early 1960's and the information presented in this paper is more of a historical review than presentation of new developments.

2. BACKGROUND TO THE ADOPTION OF ASA-3

Interest in the use of some method to overcome the problems associated with electrostatic charge generation during aircraft refuelling was shown by the RCAF after they had experienced incidents involving explosions and fires attributed to electrostatics. The first documented incident occurred in 1957 and involved two Avro CF-100 aircraft at the same location, which suffered explosions during refuelling, the incidents happening some 40 minutes apart. Between 1960 and 1962 three incidents involving T-33 training aircraft were also reported. One common factor in all these incidents was the low ambient temperatures at the time of refuelling i.e. -17°F to +13°F. A review of methods to prevent future incidents of this type led to only one practical approach and that was the use of a fuel additive to artificially increase fuel electrical conductivity. At that time Shell had been very active in the electrostatic field and had available an additive, ASA-3, which appeared to provide an answer to the problem. The RCAF at the beginning of 1962 therefore decided to investigate the use of ASA-3 and sought the co-operation of Shell and the National Research Council (NRC) for various aspects of the evaluation program.

3. PROGRAM TO EVALUATE THE USE OF ASA-3

The evaluation program was designed to cover:-

(a) Flight testing of ASA-3 treated fuel (including additive blending and fuel distribution).

(b) Investigation of charging characteristics during refuelling at low ambient temperatures (untreated fuel).

(c) Laboratory and test-rig support programs.

3.1 Flight Test Program

The flight test program was started at RCAF Station Gimli in Manitoba in the Spring of 1962 and covered mainly the refuelling of T-33 aircraft. Gimli was selected as the base because of its location in a region of low ambient temperatures and its sole source of wide-cut type fuel was a Shell refinery at Winnipeg approximately 55 miles away. The main objectives of the flight trial were:-

(a) Evaluation of problems related to blending, transportation and storage of ASA-3 treated fuel.

(b) Evaluation of the effects of ASA-3 on engines and accessory and airframe components.

(c) Evaluation of the performance of station filtration systems.

The conductivity target was set at 100-300 pS/m and no problems were encountered in meeting this at Gimli after blending in Winnipeg. The conductivity of quarantined bulk fuel depleted by about 30% after two months with no further loss over 18 months storage. Over the 2 year test period 32,500 flying hours were accumulated and over 8 million Imperial gallons of fuel dispensed. For the last eight months the additive concentration was tripled to increase severity. In May 1963 the program was extended to RCAF Station Uplands, Ottawa to allow exposure to a greater variety of aircraft. A

total of 6¼ million Imperial gallons of fuel were consumed during this extension.

No adverse effects were noted on performance or condition of engines, accessories and airframe components during the two phases of the flight evaluation. The performance of filter/separators both at Gimli and Uplands was monitored during the program and no deterioration observed.

3.2 Electrostatic Charging Program

The electrostatic charging program was conducted at RCAF Station Winnipeg during the Winter of 1963 by a team of Royal Dutch Shell and NRC personnel. This program involved the measurement of electrical properties during the fuelling of T-33 wing tip tanks (location of previously reported explosions), a CC-106, Yukon aircraft (similar to a Bristol Britannia) and an experimental tank used by Shell in previous electrostatic programs. The measurements were made at low ambient temperatures to determine the effect of such conditions on electrostatic charging. Previous incidents occurred at low temperature and this investigation was made partially to determine if this coincidence was due to an electrostatic phenomenon or because of the flammability of the wide-cut fuel at lower temperatures. The results of this program have been reported previously (1,2).*

The main conclusions reached were:-

(a) A strong reduction in fuel conductivity was observed during and after transfer through fuelling equipment.

(b) Charge concentration increased up to a fuel conductivity of about 7 pS/m.

(c) A strong increase in charge concentration, together with a further reduction in conductivity, was noted using dual filtration i.e., filter/separator and filter type monitor.

*Numbers in parenthesis denote references (Section 9).

(d) Field strengths over 400 kV/m followed by discharges were noted up to a rest conductivity of 7 pS/m in all receiving tanks. With dual filtration discharges were noted up to 30 pS/m.

(e) Most discharges occurred during final stages of filling.

(f) The continuous recording of charging currents showed that currents were much higher at the initial start of fuel flow.

(g) Supporting laboratory experiments showed that charge generation remained practically constant over a fuel temperature range of +20°C to -20°C. However as conductivity decreased with temperature change accumulation increased.

(h) Limited tests with ASA-3 treated fuel showed electrical effects at the hose end and in the tank were essentially zero.

The conclusions derived from this program provided a possible explanation for the incidents experienced by the RCAF.

(1) At low temperatures the effective conductivity is much lower than expected for a measurement of the rest conductivity. Higher charge accumulation can therefore be expected.

(2) The T-33 wing tip tank is frequently "topped-up" by an "on/off" action of the hand-held nozzle to prevent overflow. This causes periodic surges of highly charged fuel at the final and most critical stage of refuelling.

(3) The relatively smooth interior surface of the tip tank does not provide projections which can act as a source for the initiation of weak coronna type (non-incendiary) discharges.

3.3 Laboratory and Test Rig Programs

Laboratory and test rig programs were also conducted to evaluate:-

(a) Effect of ASA-3 on fuel capacitance type fuel gauges (3,4).

(b) Effect of ASA-3 on filter/separator performance.

(c) Response of ASA-3 with various fuels and fuel/additive combinations (5).

(d) Measurement of electrical conductivity (6).

The results of these programs included:

(1) Conductivities up to 1,130 pS/m had no adverse effect on gauge performance.

(2) No adverse effect of ASA-3 on filter/separator performance was noted.

(3) The response of ASA-3 varied with fuel composition but generally conductivity increased with time after initial dosage.

(4) Combination of corrosion inhibitors and ASA-3 affected conductivity response with one particular inhibitor showing a marked synergistic effect.

(5) The charged ball test procedure gave low results due to ion depletion (this work led subsequently to the development of the Maihak Conductivity Indicator and the issue of ASTM Method D2624 - the currently used field conductivity method).

4. ADOPTION OF ASA-3 IN CANADA

As a result of the success of the various programs specifications for wide-cut type and kerosine type of aviation fuels issued by the Canadian Government Specifications Board were amended in 1964 to include a mandatory requirement for an enhanced electrical conductivity. The original limits established were 50-75 pS/m at -20°F but extrapolation was allowed using the accepted equation for conductivity/temperature relationship i.e.

$$\underline{\log k_t = a(t-t_1)+\log k_{t_1}}$$

These limits have since been changed and currently limits in the CGSB Specifications measured at time and temperature of delivery to purchaser are:-

<u>CAN2-3.22-M80</u> (Wide-cut fuel)

Grade Jet B: 50-450 pS/m

Grade F-40 : 100-600 pS/m

<u>CAN2-3.23-M80</u> (Kerosine fuel)

Grades Jet A-1 and Jet A-2: 50-450 pS/m

At the present time specifications only reflect the use of Shell ASA-3 although consideration will probably be given to allow the use of Stadis 450 as well, following the USAF approval of this additive. A new Department of National Defense Specification DND-22 (NATO F-40) which becomes effective in 1981 allows the use of both additives with a conductivity limit of 100-600 pS/m.

Shell ASA-3 has therefore been used in all Canadian produced kerosine and wide-cut turbine fuel since 1964. No problems have been reported as a result of using the additive. The additive used in Canada is designated ASA-350, which is a 50% strength solution of the ASA-3 available at other locations. The additive is normally blended at the refinery where experience over the years has dictated the level of blending required to meet specification limits on delivery to the purchaser. Depletion in conductivity during transportation varies with the method used and losses up to 50% could be encountered in certain pipeline systems. Where experience has shown that depletion can be expected re-injection of additive at terminals is sometimes used. Since the additive is readily soluble in fuel,blending is not a difficult problem. Consideration is also given to the long term storage of product and drum stocks

for Northern storage for example are treated to obtain conductivities towards the upper specification limit.

5. ADOPTION OF STATIC DISSIPATER ADDITIVE OUTSIDE CANADA

The results of the initial RCAF/Shell/NRC programs were presented to the International Air Transport Association (IATA) in December 1963. The IATA Guidance Material for Aviation Turbine Fuels was amended to allow the use of an approved static dissipator additive. In October 1968 the addition of ASA-3 was also made mandatory in turbine fuel in the United Kingdom. The use of static dissipator additive has spread since that time with the United States being one of the few areas in which it was not used, that is until the recent adoption by the USAF.

At the June 1980 NATO/MAS Meeting in Brussels agreement was reached to make the use of static dissipator additive mandatory in the NATO Standardization Agreement, STANAG 3747 "Guide Specifications (Minimum Quality Standards) for Aviation Turbine Fuels", with a limit of 100-600 pS/m. Other NATO, STANAGS covering the pipeline systems will be amended accordingly in course of time.

6. STATIC DISSIPATOR ADDITIVE AND WSIM REQUIREMENTS

Since ASA-3 contains a surface-active ingredient it does have a detrimental effect upon the Water Separation Index, Modified (WSIM) rating of a fuel. A program, part of a NATO study, to assess the effect of ASA-3 on WSIM was carried out in conjunction with single-element testing (Ref. 7). In summary the results obtained showed that the extent of WSIM reduction with ASA-3 depended upon the original WSIM of the fuel. With a good WSIM fuel i.e. >90, addition of 1ppm ASA-3 gave a reduction of about 10 to 15 numbers. Using corrosion inhibitors (without ASA-3) gave a slightly greater reduction. In the majority of cases however the combination of ASA-3 and corrosion inhibitors had a synergistic effect on WSIM.

The single element testing showed that with ASA-3 or corrosion inhibitor (not in combination) a WSIM level of 75 was quite satisfactory. The filter coalescer elements used in this program were of an older type and subsequent in-house work has shown that with elements approved to Mil-F-8901C or API Bulletin 1581 the effect of ASA-3 and Stadis 450 on water removal performance is satisfactory with fuel with WSIM values lower than 75. Canadian specifications for wide-cut and kerosine fuels currently require a minimum WSIM of 75. Problems are sometimes encountered in meeting this level in multi-product pipeline systems and waivers are sometimes required. Experience in Canada since the inception of ASA-3 has shown no serious adverse effect on filter/separator performance. It should be pointed out that corrosion inhibitor is not normally used in Canadian jet fuels and the experience reported is based upon ASA-3 alone. Later experience in the United Kingdom, who currently require both additives, has shown no adverse effect on filter/separator performance.

7. STATIC DISSIPATOR ADDITIVE IN NON-AVIATION FUELS

In the Winter of 1972/73 two incidents occurred at Montreal during a switch loading operation. The distillate fuel in question was found to have high charging properties and was responsible for both incidents. As a result static dissipator additive (not necessarily ASA-3) is now used in a large majority, if not all, distillate fuels produced in Canada.

8. CONCLUSION

Static dissipator additive has been used in all Canadian wide-cut and kerosine type jet fuel since 1964. No serious problems arising from its use have been reported. Canadian experience is supported by other countries since its use has subsequently become widespread. With current and future fuel supply problems the possibility of using reduced flash point fuels or using more wide-cut fuel become more

distinct. The use of static dissipator additive during refuelling operations with these fuels adds a degree of safety and will help retain the present excellent safety record of aviation fuel handling.

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CONDUCTIVITY ADDITIVE IN JP-4 AND JP-8

by

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CONDUCTIVITY ADDITIVE IN JP-4 and JP-8

This paper discusses the status of the implementation program to inject conductivity additive in JP-4 and JP-8 worldwide. It also covers why it was initiated and some of the problems associated with additive use.

Between 1966 and 1974 static electricity caused 30 major Air Force accidents which resulted in substantial losses, including 7 fatalities and total destruction of 5 aircraft. From 1974 thru 1977, the Air Force experienced eight aircraft fuel system fires during refueling. All aircraft involved had tanks packed with reticulated polyurethane foam.

This rash of mishaps prompted formation in 1977 of an AF AD HOC Committee on Static Electricity to establish programs to identify and correct the causes of these electrostatic fires. One of the actions of this committee was to conduct a service test on the use of conductivity additive in JP-4. The Quality Division of the Directorate of Energy Management was assigned responsibility to conduct this test.

The two additives tested at eight Air Force bases and one DFSP (for long term stability) were ASA-3, a Shell Chemical Co. product and STADIS 450 made by du Pont. These additives at a concentration of about 1PPM increase the conductivity of fuel which allows electrostatic charges to dissipate quickly and not accummulate to dangerous levels.

The test started in April 1977 and after satisfactory results was approved by HQ USAF/LEY in May 1979. The Army and Navy also approved the additive in May 1979 through coordinated changes to the JP-4 and JP-8 specifications. Earlier problems with STADIS 450 resulted in removing this product six months after start of the test. However, test data showed it was satisfactory and as a result was approved for use in early 1980.

From 1978 to the present, the Air Force has continued to experience electrostatic mishaps. These include 14 more aircraft internal tank fires and total destruction of a KC-135 and an R-5 refueler. These occurred at sites not using conductivity additive. In addition to the eight test sites and primarily to correct occurrences of electrostatic incidents, 16 more bases have been placed on the additive. Additive use in JP-8 at all UK bases was completed in July 1979. The Bitburg Loop of the Central European Pipeline System serving three US and two German bases was doped in April 1980 and will act as a test base for NATO acceptance.

While the overall test program was considered highly successful, there were some isolated problem areas. Two occurrences of high conductivity fuel (approximately 1200 CU) were experienced at Myrtle Beach AFB. It was found that some shipments of JP-4 into the supplying terminal at Charleston DFSP already contained the additive and subsequent injection by the contractor at Myrtle Beach resulted in twice the normal quantity. To prevent recurrence, fuel is now checked for conductivity prior to addition of the additive.

The reason for low conductivity at Mt Home AFB ID has not yet been explained. Fuel at the supporting terminal which is received from Salt Lake via multi-product pipeline has a poor response to the additive. Approximately 2 parts per million of additive are required to obtain CU levels of near 120. The low response of fuel at the Southern Pacific Pipeline terminal which supports Travis AFB was found to be a weak batch of ASA-3.

At McChord AFB, there were two problems. Constant problems have been experienced with high filtration time fuel which results in changing filter separators at a high frequency. While extensive work did show that ASA-3 contributed to this condition, many other fuel batches prior to addition of the additive were near the maximum filtration time limit of 15 minutes. The second problem at McChord was the occurrence of low order fires in two filter separator vessels after element change. It is pointed out, however, that initial filling of vessels after element change is a hazardous procedure with or without the additive. To reduce or eliminate this hazard, vessels are now required to be gravity filled.

The conductivity response of fuel to additive cannot always be predicted based upon several factors. Most corrosion inhibitors decrease the resultant conductivity level although one reacts to give a higher value. Cleanliness of the fuel also affects response, i.e., the cleaner the fuel, the better the response. Nitrogen content is also a factor—a high nitrogen level will depress the conductivity value. Temperature is perhaps the most significant factor—the higher the temperature, the higher the conductivity. It has also been experienced that the amount of STADIS 450 is normally 1-1/2 times that of ASA-3 to obtain the same conductivity level. At these injection levels, the cost of the two additives is about equal.

The initial target date of April 1980 for implementing the additive in JP-4 worldwide was obviously not met. This was due to delays in procuring the EMCEE Electronics Inc. conductivity meters in addition to not all contractors having injection systems installed. Implementation on a wide scale started in August 1980 and by October 1980 approximately 70 percent of CONUS bases were receiving the additive. In most overseas areas where government owned, government operated terminals are involved the start date will probably not occur until mid-1981. Following are Army and Navy-operated Defense Fuel Supply Points where additive injection systems will be installed.

Army	Navy
Anchorage, Alaska	Norfolk (Yorktown), Virginia
Kuwae, Okinawa	Jacksonville, Florida
Chim-Wan, Okinawa	Keflavik, Iceland
Kunsan, Korea	Tsurumi, Japan
Pyongtaek, Korea	Arraijan, Canal Zone
Osan, Korea	NSD Guam
Taegu, Korea	
Waegwan, Korea	
Taejon, Korea	
Suwon, Korea	
Uijong-Bu, Korea	
Pohang, Korea	

In most cases, additive is injected at either the refinery or the terminal supporting the base. This is governed by the source of supply to each base. Where a base receives product directly from a refinery, the additive is normally injected during product loading. This injection location is to permit retention of the WSIM requirement in the JP-4 and JP-8 specifications prior to blending the additive. Where bases receive JP-4 from terminals, the general rule is to inject on receipt at the terminal. At this time, the additive is not added in tanker loadings or in multiproduct pipelines since excessive CU losses occur.

Cost of adding ASA-3 or STADIS 450 to worldwide JP-4 and JP-8 stocks is estimated at $1 million a year with an initial startup cost of approximately $1 million.

Some of the more frequent questions asked about the additive are:

(Q) What is the effect of high and low conductivity?

(A) The maximum use limit of 700 CU was established to prevent erratic readings in fuel quantity gauge systems of aircraft. The minimum use limit of 100 was set based upon research studies which showed this value was needed to prevent a hazardous condition in fueling of aircraft tanks containing the new type polyether blue foam. The specification limits are 200 to 600 CU.

(Q) Does additive poison filter separator elements?

(A) Single element tests performed at test bases by Kelly AFB personnel showed there is negligible effect on element performance.

(Q) Does it destroy the WSIM property of fuel?

(A) The average decrease in WSIM after addition of the additive is 15 numbers. The effect is less if the WSIM of the base fuel is high, and conversely as the WSIM of the base fuel nears the minimum specification limit of 70, the degrading effect increases. Consequently, once ASA-3 or STADIS 450 is added, there is no limit on WSIM. However, suppliers must verify the fuel meets the 70 minimum without conductivity additive.

(Q) Is a small quantity of additive more hazardous than none at all?

(A) This is perhaps the most asked question and by far the most controversial. While it is recognized there can be a situation where the conductivity is not sufficient to overcome the additional charge the additive inherently gives the fuel, the chances of this occurring are extremely remote. To support this the conductivity of the fuel in every electrostatic mishap was below 10 CU, which is typical of nonadditive fuel. Additionally, test results on JP-4 throughout the Air Force and particularly in Europe have shown a wide range of conductivity values between 10 and 60 CU. Supposedly the danger area is somewhere between 15 and 25 CU. Consequently, all the experts generally agree that in most all situations any increase at all in fuel conductivity, regardless of the end value, provides a safer electrostatic condition.

(Q) Does ASA-3 lose strength? Does STADIS 450?

(A) Shell Chemical reports that ASA-3 will lose strength of about 25 percent in one year. E.I. du Pont reports that STADIS 450 is stable for an indefinite period.

(Q) What is temperature effect on conductivity?

(A) An increase in temperature increases conductivity and conversely a decrease in temperature decreases conductivity. These relationships vary somewhat depending on the fuel, but as an example, a conductivity of 150 CU at 60^{o} F should have a conductivity of 120 at 40^{o} F and 210 at 80^{o} F.

WASTE PETROLEUM RECLAMATION AND REUSE

PRESENTED BY

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DEPARTMENT OF ENERGY
BARTLESVILLE ENERGY TECHNOLOGY CENTER

PRESENTED TO THE
INDUSTRY-MILITARY ENERGY SYMPOSIUM
21-23 OCTOBER 1980
SAN ANTONIO, TEXAS

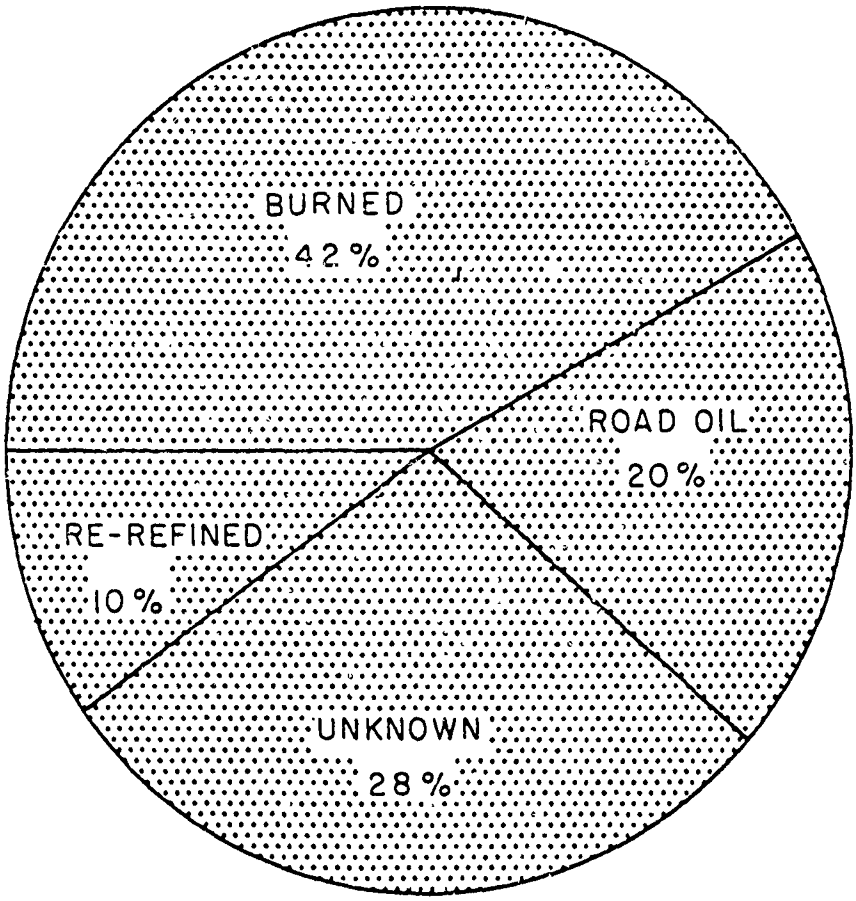
USED OIL RECYCLING:

CONSERVING PETROLEUM,

DECREASING POLLUTION

BARTLESVILLE ENERGY TECHNOLOGY CENTER
BARTLESVILLE, OKLAHOMA

DISPOSAL OF WASTE OIL



TOTAL WASTE OIL: 1.2 BILLION GALLONS

USED OIL RECYCLING

DIRECT USE

REPROCESS

RECLAIM

REREFINE

REPROCESSING

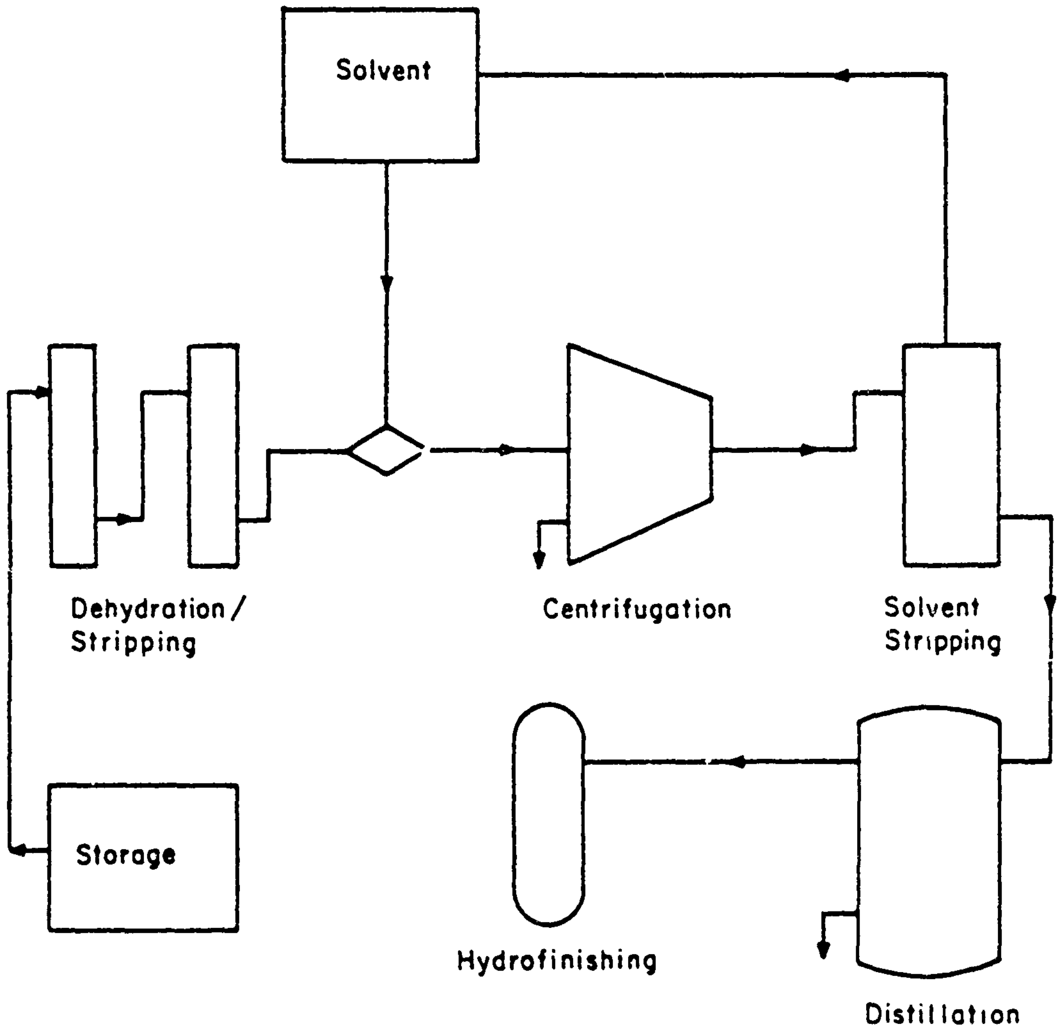
SETTLING HEAT FILTRATION	FUEL

RECLAMATION

SETTLING HEAT FILTRATION CENTRIFUGATION	OIL

REREFINING

DISTILLATION CHEMICAL TREATMENT CLAY OR HYDROGEN FINISHING	LUBE OIL


Solvent
Dehydration / Stripping
Centrifugation
Solvent Stripping
Storage
Hydrofinishing
Distillation

ECONOMIC/ENERGY BALANCE

ADVANTAGE TO U.S. OF REREFINING OVER BURNING USED OIL

- $262 MILLION
- 7.94 MILLION BBL OIL

FIGURE 7. - ENERGY POLICY AND CONSERVATION ACT OF 1975

SECTION ON RECYCLED OIL

1. TO ENCOURAGE THE RECYCLING OF USED OIL
2. TO PROMOTE THE USE OF RECYCLED OIL
3. TO REDUCE CONSUMPTION OF NEW OIL
4. TO REDUCE ENVIRONMENTAL HAZARDS AND WASTE

RESOURCE CONSERVATION AND RECOVERY ACT OF 1976

FEDERAL PROCUREMENT SECTION

"...., EACH PROCURING AGENCY SHALL PROCURE ITEMS COMPOSED OF THE HIGHEST PERCENTAGE OF RECOVERED MATERIALS PRACTICABLE...."

MIL-L-46152

20 NOVEMBER, 1970

"NO RE-REFINED CONSTITUENT MATERIALS
SHALL BE USED."

MIL-L-46152A

(PROPOSED)

"MAY BE VIRGIN OR REREFINED STOCKS
OR A COMBINATION THEREOF"

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HARRY R. JOHNSON, Director

AUGUST 1980

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A NEW TECHNIQUE TO EVALUATE PERFORMANCE OF JET FUEL FILTRATION EQUIPMENT

PRESENTED BY

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PRESENTED TO THE
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21-23 OCTOBER 1980
SAN ANTONIO, TEXAS

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800771

A New Technique to Evaluate Performance of Jet Fuel Filtration Equipment

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Linden, NJ

FOR SOME TIME THE NEED HAS BEEN RECOGNIZED by the aircraft fueling industry(1)* for a small-scale test technique to assess the on-going performance and end of the useful life of filter/separator (F/S) and clay treatment elements. Normally, filter-separator elements are "changed-out" on a differential pressure or time basis only. Filter/separator elements which fail by solids accumulation give warning by increased pressure differential, but the degraded nature of the filter coalescer that has been deactivated for water coalescence is not obvious until water is detected in the influent and effluent. Likewise, the ability of clay treatment elements to adsorb surfactant-type contaminants in aviation fuels is not obvious until the effluent fuel fails to shed water contamination.

It is known that the performance of a filter/separator or clay treatment unit at any given time is a function of the cumulative history of the fuel contaminants to which they have been exposed. For instance, it has been shown that satisfactory coalescence performance can be restored to a deactivated coalescer element by flushing the element with clean fuel.(12) Restoration of coalescence can also be achieved by flushing with large quantities of water in the fuel.(2) Therefore, for a test technique to adequately assess F/S performance, it must take into account the prior use history of the elements as well as employ a simple technique for measuring that performance.

Exxon has, over the past few years, been developing a sidestream monitoring technique to assess the current performance of filter/separators and clay treatment elements. This technique has undergone extensive laboratory and full-scale testing. This paper describes the technique which has been developed and presents data on several factors which have been studied and found to play an important role in filter deactivation.

The Filter Sidestream Sensor (FSS) has been undergoing field tests for over two years at several Exxon affiliate locations. At some of these locations use of the Sensor has resulted in direct cost savings by permitting extended service life of filter elements beyond the normal change-out period. However, because of the overall surfactant-free service in most of these systems under test, only a limited amount of deactivation data has been obtained to date. In an effort to expedite the validation of this technique and gain more field experience, Exxon is releasing the Filter Sidestream Sensor for cooperative industry testing through the Coordinating Research Council and the Institute of Petroleum.

BACKGROUND

Water and solids (dirt) are critical contaminants in aviation jet type fuels. Excessive solids may plug aircraft filters and/or cause engine fuel system malfunctions while free water may induce corrosion, microbial growth, or icing problems with

*Numbers in parenthesis designate References at end of paper.

ABSTRACT

A new jet fuel filtration monitoring system and technique is described which provides an assessment of the current performance and signals the end of the useful life of filter/separator and clay treatment elements. The need for such a system has long been recognized by the aircraft fueling industry to indicate when surface active agent type contaminants in jet fuels are no longer efficiently removed by clay treatment and/or interfere with the water coalescence function of the filter separator. The system, which has been developed and called a Filter Sidestream Sensor, operates on a sidestream with dynamic similarity to the main filter separator or clay vessel. It has been designed to provide a cumulative history of all factors which affect filter performance. Correlations between Filter Sidestream Sensor and main filter performance are provided together with data on the effects of surfactants—both natural and additive types, and the role played by water in coalescence deactivation.

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low temperature operation. Surface active agents (surfactants) reduce the ability of filters to remove both dirt and water and are therefore also considered contaminants. To control jet fuel contamination, filtration and water removal units called filter/separators (F/S) were developed in the 1950's jointly by military and commercial interests.[3] In the early 1960's surfactants were recognized to cause disarming of F/S which led to the use of clay units to remove these surfactants and protect the F/S. Today, filter/separators and clay units are used extensively in turbine fuel handling systems and play a key role to ensure that aviation customers receive clean and dry fuel.

A typical turbine fuel handling system is shown in schematic form in Figure 1. Turbine fuel is shipped from the refinery to one or more terminals via pipeline or barge where it is received into tankage. From the terminal, fuel is transported by truck, rail, pipeline or barge to other terminals and then to airport storage. Fueling into plane is done by tank truck or from a hydrant system through a hydrant servicer. On all fueling vehicles and at each transfer point, fuel is filtered through a filter/separator. In addition, bed-type clay treatment units are commonly used in refineries and smaller clay cartridge units are often employed at downstream terminal facilities at the end of multi-product handling systems. Clay units are precluded where fuels are treated with additives at the refinery since clay removes these materials.

Figure 2 presents a cutaway view of a clay cartridge treatment unit and a filter/separator used in turbine fuel handling systems. Clay treatment is sometimes used to remove organic color bodies as well as surfactants which may have been present in the fuel at the time of manufacture or may have been picked up when handled in multiproduct transportation systems such as pipelines. Clay treatment with cartridge-type elements is used extensively in the United States at terminals. Contaminated fuel enters the vessel and passes from outside-in through the elements to the vessel outlet. A typical clay cartridge vessel may have flow capacities of 600 gallons per minute and contain approximately 90 cartridge type elements.

Most filter/separators consist of two filtration and stripping stages which perform three functions when presented with a flowing stream of fuel containing water-in-oil emulsion and/or dispersed particles. These are (1) filtration or solids removal, (2) coalescence of finely emulsified water droplets into larger droplets, and (3) separation of the water droplets from the flowing stream of fuel by a hydrophobic barrier.

As indicated in Figure 2, the first two functions are usually combined in a fiberglass element called the filter-coalescer created by wrapping different layers of resin-treated fiberglass around a cylindrical core of metal screen or pleated paper and covering the wrappings with a woven fabric shroud. The separation function is usually performed in a separate element created by a cylinder made of a metal screen or paper of specific pore size which has been treated to be hydrophobic.

The key to ensuring maintenance of product quality and delivery of clean and dry fuel is, of course, use of test proven equipment[10], proper maintenance of these filters together with direct measurements, field observation, and performance checks of the entire handling system.[4]

At present, there are two main criteria for filter/separator element changeout—differential pressure buildup, or time in service. Pressure buildup from particulate filtering is easy to monitor with pressure gages. However, in the absence of pressure buildup, the filters are changed on a time basis. Neither of these criteria address the possibility that the filter/separator is no longer able to coalesce and separate free water.

Changeout of clay treatment elements occurs primarily when WSIM or Millipore color ratings cannot be maintained or improved to prescribed limits. Clay may also be changed due to high differential pressure or when clay carryover is noted in downstream filters.

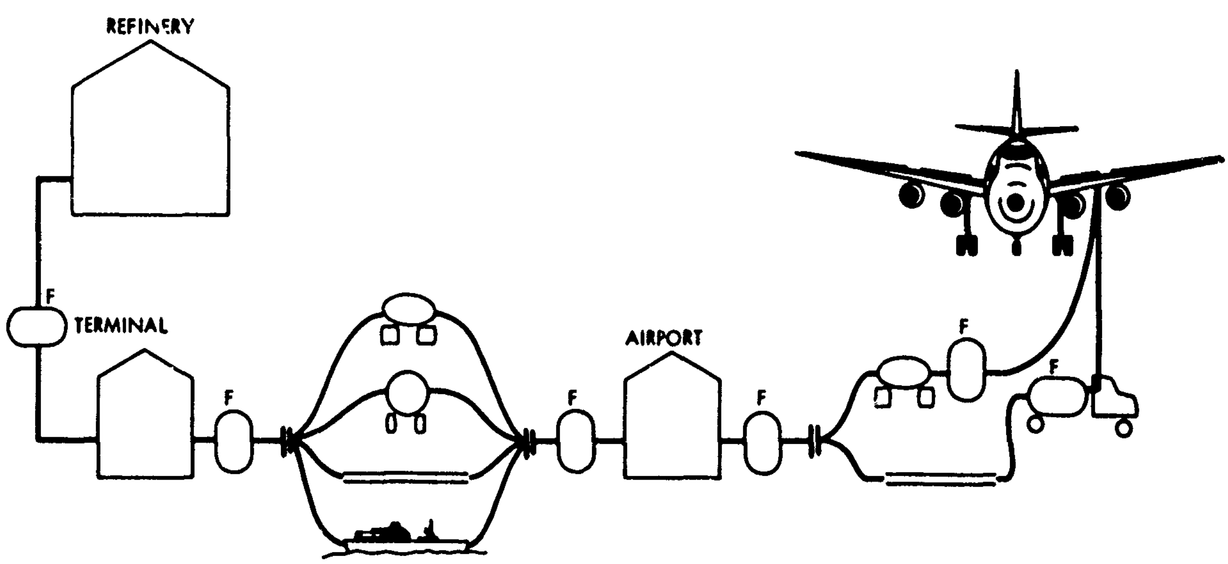

Figure 1. Typical jet feed handling system.

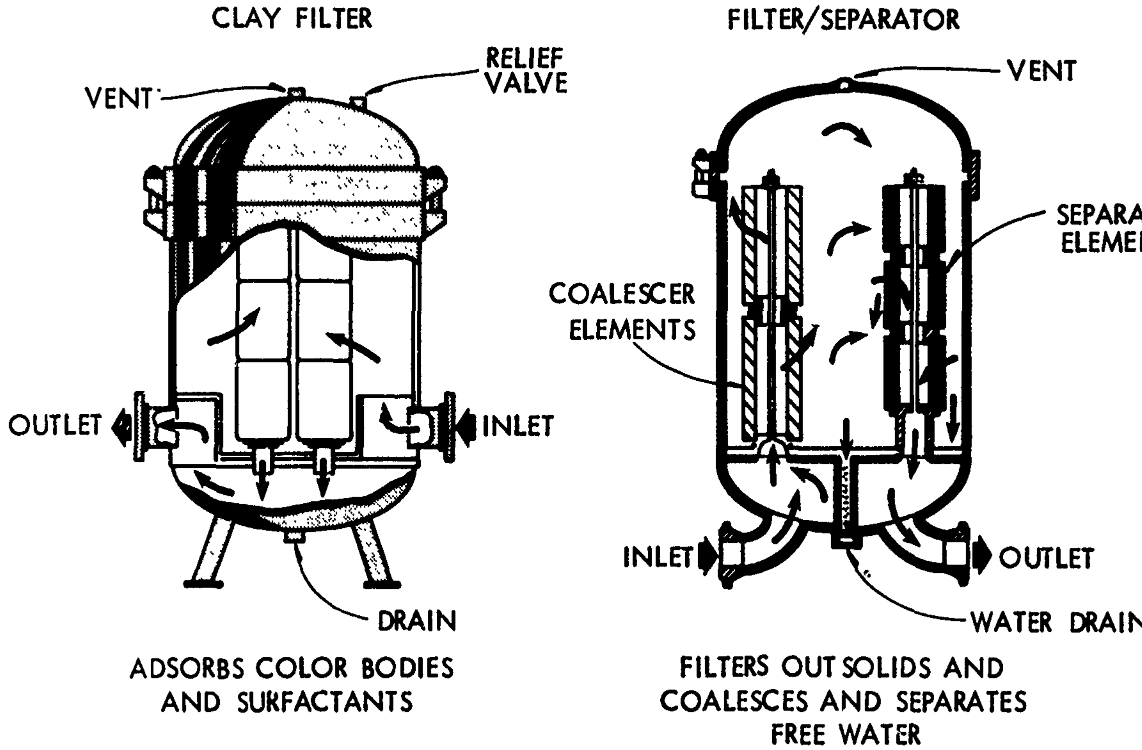

Figure 2. Filter types.

The following sections describe a technique which we have developed to predict the performance and remaining activity of filter/separators to coalesce free water, and clay filters to adsorb surfactants.

DISCUSSION

Description of the Filter Sidestream Sensor (FSS)

The monitoring technique which has been developed operates on a sidestream with dynamic similarity to the main filter/separator. Dynamic similarity between sensor and main filter is provided by maintaining geometric construction similarities in the sensor. Sidestream operation provides two major advantages to other approaches. First, it provides a cumulative history of all factors which affect filter performance, and second, evaluation of the sidestream sensor can be made independently of whether the main filter is operating at the time or not.

Figure 3 shows the Sidestream Sensor assembly together with the sampling probes. These probes, sanctioned by ASTM for contaminant sampling in jet fuels are inserted into the center portion of the main line flow stream. Flow enters the sidestream through the inlet probe and is controlled by the valve on the rotameter. Once set, the valved rotameter maintains a proportional flow to the sensor with variations in main line flow. From the rotameter, the flow is directed through the sensor holder containing the sectioned filter components and then back to the main line downstream of the main filter. The differential pressure across the main filter provides the driving force through the sidestream.

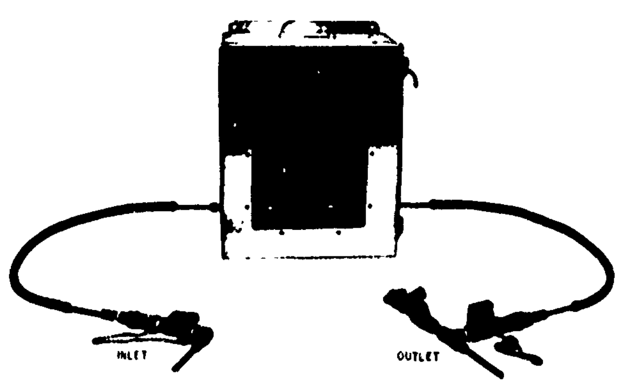

Figure 3. Filter sidestream sensor.

Figure 4 is a picture of several Sidestream Sensors installed on full scale filter/separator and clay treatment vessels. The Sensors are shown at the base of each vessel. Shown here are, left to right, a 1900 gpm filter/separator, a 600 gpm clay filter, and a 600 gpm filter/separator. These units are similar to those found in terminals or airport fueling fixed facilities.

Periodically, the Sensor holder containing the cross section of the filter is removed from the box and tested for remaining filter activity. The ASTM D 3602 Mini-Sonic Separometer (MSS) or ASTM approved Micro-Separometer is used for this testing. Reference fuel containing a prescribed amount of contaminant (water for F/S Sensor and surfactant for the Clay Sensor) is passed through the Sensor at 200% of rated flow capacity. A WSIM determination by MSS or Micro-Separometer is run on the Clay Sensor effluent, while the effluent from the F/S Sensor is measured for relative turbidity in the MSS appar-

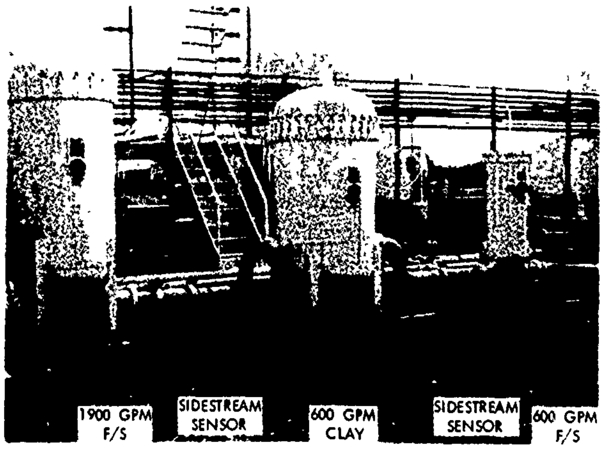

Figure 4. Full scale filter test facility for aviation fuel.

tus. The more cloud in the effluent, the lower the remaining activity of the Sensor and by inference, the elements within the vessel. Because of parametric symmetry between Sensor and main elements, activity of the main system can be estimated from the activity of the Sensor. The use of the Sidestream Sensor is intended to serve as a guide to the quality of the filter effluent and to supplement other existing operational and performance criteria of the main filter system.

USE OF THE FSS AS A SENSOR OF F/S PERFORMANCE

The Nature of Coalescence and Coalescence Deactivation

The performance of filter/separators for water and dirt removal degrades when the fuel contains trace constituents or contaminants of surface active agents (surfactants). Trace surfactants may be present in the fuel at the time of manufacture or may be picked up by jet fuel when handled in multiproduct transportation systems such as pipelines. Aviation jet fuels may also contain different types of additives to impart special fuel properties and these additives may have surfactancy qualities. Fuel additives are used to control corrosion of pipelines and storage tanks, increase electrical conductivity, provide anti-icing properties, increase fuel lubricity, inhibit fuel oxidation, increase thermal oxidation stability, and deactivate dissolved metals. Experience has shown that some additives hasten the deactivation[2,5,6] of coalescers and separators.

The critical factors involved in coalescence in a fibrous bed have been described by R. N. Hazlett[7]. These factors can be grouped under three main mechanisms - approach of a droplet to a fiber, attachment of a droplet to a fiber, and release of an enlarged droplet from a fiber. The efficiency of the approach mechanism is mainly controlled by hydrodynamic factors such as fiber size, particle size of the droplet, differential density and fuel viscosity. Although particles or droplets carry electrostatic charges, attraction or repulsion effects play a secondary role in coalescence. The droplets of water attach to a fiber where they grow by further droplet interception. When a droplet approaches an already attached drop, two interfacial films must be ruptured - thus surfactants that affect droplet deformability affect coalescence. As the drops grow, several fibers are wetted simultaneously and threads of water move through the fiber bed. The size of the drops and threads is governed by a balance between the flow forces of the fuel and the adhesive forces between water and fiber. These threads merge to form streams of water which collect as balloons of water on the bed exit fabric covering from which they are released. Type and amount of surfactant in the fuel, fiber size, and flow turbulence all play important roles in the size of the released drop. Higher surfactant concentrations, smaller fibers, and increased turbulence tend to cause premature release and, consequently, smaller droplets.

A typical coalescer deactivation curve is shown in Figure 5. Here is shown the relative coalescer activity for an additive treated jet fuel as a function of fuel volume throughput. Also shown is the effect of element rated flow capacity, i.e., relative flow velocity, on coalescer activity. Initially, satisfactory performance was obtained on this coalescer, as indicated by a relative activity of 100, and was maintained until approximately 100 gallons had passed through the test pad. At this point, loss of coalescer activity occurred suddenly and with little warning on this additive treated fuel. Increasing the flow capacity to 150% gave an earlier loss of activity, but with a slight forewarning. Reduction in flow rate tends to provide a longer period of activity.

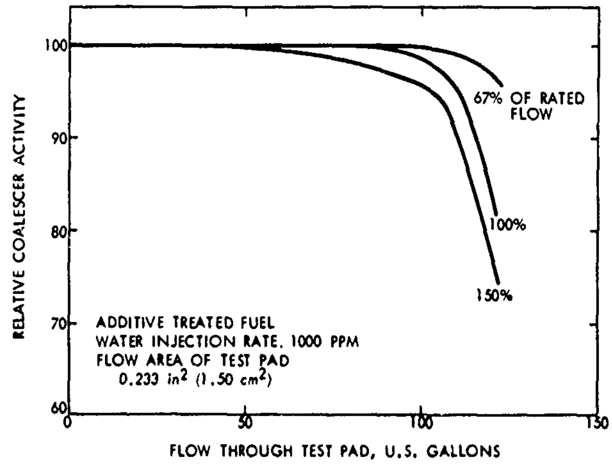

Figure 5. Typical coalescer deactivation as a function of flow rate.

Filtration of solids (a function combined into a coalescer element) inherently degrades water coalescing action. In the presence of surfactants, solids are kept dispersed and travel deeper into the bed where they alter wetting and adhesion characteristics of the bed to water. Solids may also carry surfactants through the bed to affect the water release mechanisms. For this reason, some filters which are designed for surfactant environments utilize extra filtration media to prevent solids migration into the bed.

Construction of the Sidestream Sensor for Filter/Separators

Dynamic similarity between the Sensor and main filter is provided by maintaining geometric construction similarity of

the Sensor. Figure 6 shows two types of sectioned coalescers. Each component of these coalescers performs a particular function. Solids filtration is accomplished on the pleated paper or inner surface. Free water coalescence is initiated on contact or collision of droplets with paper and fiberglass fibers and proceeds radially outward to the outer surface where the water droplets collect and grow on the outer woven sock. Coalesced water droplets are then released by gravity forces from the sock and collect in the main filter sump. As indicated in Figure 6, each component of the Sensor is cut from a filter identical to the coalescer element contained in the main filter, and placed in a Sensor holder. Each component section is gasketed in the holder to provide an exact duplication of the flow per unit area of each component of the main element. In the case of the pleated paper component, a proportionally larger flow area is provided in the Sensor to compensate for the greater area of pleated paper. This is indicated in Figure 6 by the drawn ellipse in the cone superimposed over the filter. Flow through the Sensor is proportioned to the flow in the main elements. In addition, changeout of the Sensor is made to coincide with changeout of the main elements. Thus, as designed, the Sensor is exposed to the identical cumulative history of fuel contaminants as the main vessel elements. The importance of duplicating the cumulative history of the main filter becomes readily apparent when consideration is given to the factors which affect filter/separator performance. Some of the more important factors and their effects on performance are discussed below.

- The Role of Water in Deactivation

It is known that the type of water and the amount of water in the presence of surfactants play important roles in the speed at which coalescers deactivate. Research has shown that sea water causes faster deactivation of coalescers than distilled water. This is demonstrated in Table I for two different coalescers. The data also indicate that Filter C has an apparent greater tolerance to sea water before deactivation than Filter D. The reason for the effect of water type on deactivation and differences between filters is not fully understood, but it is postulated that dissolved solids or compounds in sea and/or tap waters may react with surfactants and in turn the coalescer structure and hasten coalescer deactivation. Differences between tap and distilled waters have also been reported by Linder and Martel[5] on water separation studies with fuels containing corrosion inhibitors.

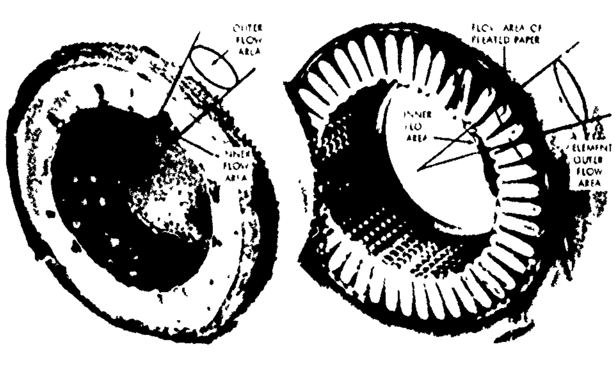

Figure 6. Sectioned filter coalescer elements.

Studies by Exxon Research in coalescer deactivation have shown that the amount of water present in fuel contaminated with surfactant is critical to the speed at which deactivation occurs. Experience has shown that with surfactants present and no water present, no deactivation of coalescence occurs. Evidence of a dramatic improvement in coalescer life has been shown when fuel is free of water. Porter, Deits, Bert, and Anderson[8] have also shown that the installation of a salt drier into their fueling system which reduced both free water as well as about 30% of the dissolved water below saturation level of the fuel, caused a greatly increased life of downstream filter-coalescers in their system. We have also shown that with small quantities (100 ppm) of water present, deactivation is relatively rapid. As the water levels in fuel reach the 1000 ppm level, deactivation of coalescer elements in surfactant fuels is very slow. This is demonstrated in Figure 7. With an influent water level of 1000 ppm, Filter A showed only a slight increase in effluent water level over the test period of 120 hours. At a 100 ppm influent water level the same filter showed an immediate and continued increase of water in the effluent with a sudden increase occurring after 60 hours. It is theorized that the balance between the hydrophilic-lypophilic balance of the surfactant, the partition concentration of these surfactants to the available water, and the subsequent contact and disposition of the surfactants on the coalescer fibers determine the speed of deactivation.

- The Role of Surfactants in Deactivation

It is well known that surfactants tend to disarm or deactivate filter/separators. Surfactants present in turbine fuel may

TABLE I

TYPE OF WATER AFFECTS SPEED OF COALESCER DEACTIVATION

Variable	Filter	Additives	Gallons Through Test Pad Before Deactivation(2)
Distilled Water	C	W/Y	1386 No deact.
Syn. Sea Water(1)	C	W/Y	620
Syn. Sea Water	C	W/Y	500
Distilled Water	D	W/Y	1463 No deact.
Syn. Sea Water	D	W/Y	233
Syn. Sea Water	D	W/Y	208

(1) Synthetic Sea Water - "Sea-Rite," a simulated sea water from Lake Products Co., St. Louis, MO.

(2) Deactivation defined as an 85 Filter Sidestream Sensor Rating.

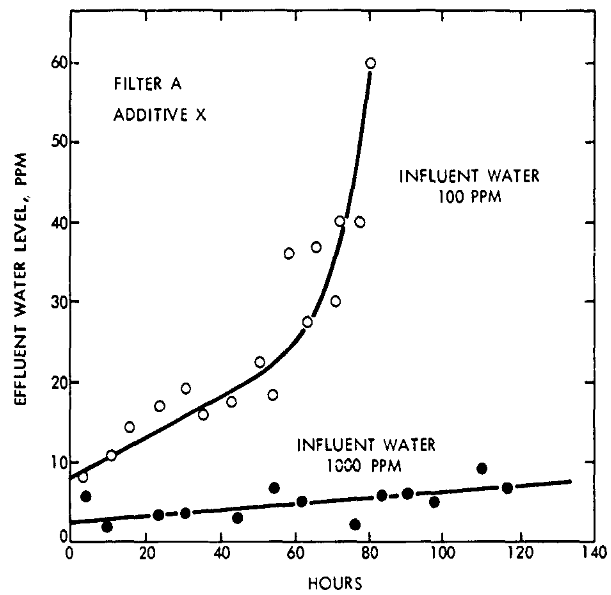

Figure 7. Amount of water in fuel affects speed of coalescer deactivation.

be classified as either natural or additive. Natural surfactants are carried over from refinery processes - one of the most common surfactants being sulfonates. Additives are used in jet fuel to inhibit oxidation, corrosion, electrostatic effects, etc. Many of these additives have some degree of surfactancy. In addition, surfactant additives are used in other products such as gasoline or distillate fuel and these can sometimes be picked up from pipelines as jet fuel contaminants.

The effects of these two different type surfactants on Sensor Rating and main element effluent are shown in Figure 8. Here is shown the effects of a commercial fuel additive, Additive W, and a naturally occurring type surfactant, Additive X,

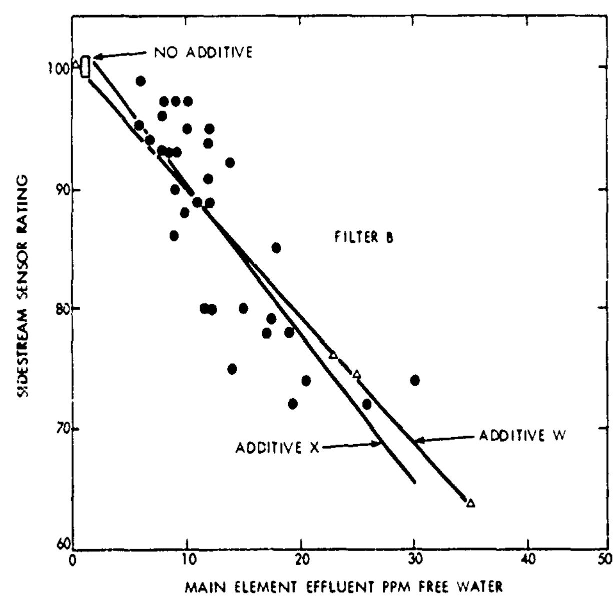

Figure 8. Effect of additive type on Sensor-main element correlations.

on a commercial coalescer element. While different concentrations of additives W and X were used, and deactivation times were shorter with Additive X than W, both were found to have a similar effect on Sidestream Sensor rating and water in main F/S effluent. That is, Sensor rating and main F/S effluent water level appear independent of additive type. The linear, least-squares equation for the data obtained for Additive W is $y = -1.025\,x + 100.02$ while for Additive X, the equation for Additive X data is $y = -1.251\,x + 103.27$ where y and x are Sidestream Sensor Rating and Effluent Water Level, respectively. When no surface active agent is in the fuel, no deactivation of the element occurs as shown by the data point in the upper left corner of Figure 8.

While the end effect of different types of surfactants on coalescence appears to be the same, it should be recognized, however, that the time before deactivation occurs varies between surfactant or additive types. Time to deactivate is also dependent, of course, on surfactant concentration as well as additive interactions. The relative time difference for the onset of deactivation between additives and additive interaction is demonstrated in Table II. The data show that each individual additive shows differences in the time to deactivate a filter coalescer. When combined, these particular additives exhibit a completely different deactivation time - not a shorter or an average time of the individual additives, but a longer time. It is theorized that perhaps these particular additives when combined form micelles or interreact, thus altering their attraction to water (polarity) or water wettability compared to their individual characteristics in jet fuel. Interference of the attraction to water will, of course, result in slower deposition of surfactants on the water wettable fibers of the coalescer and, in turn, a slower rate in the deactivation of these surfaces. Whatever the cause, it is clear that different additives cause different times for coalescer deactivation.

- Combined Water/Additive Effects

In the previous sections, the singular variable effects of additives and/or water were presented while the other variable was held constant. But in actual fuel systems, it is not unusual to have both free water and surfactant additive concentration varying from one fuel receipt to the next.

Figure 9 presents full-scale rig data on the effects of combined free water/additive variations on coalescer performance in terms of time for deactivation. In this study, fuel treated with Additive W was introduced along with approximately 20 ppm of free water into a coalescer. Deactivation was relatively rapid. Water injection was then increased to 100 ppm over a short period (~ 15 minutes) which caused a partial restoration of coalescence which quickly degraded again upon return to a 20 ppm water injection. Water injection was again increased to first 100 ppm and then 500 ppm over a period of slightly more than one hour. Again water coalescence was partially restored as indicated by the higher Sidestream Sensor ratings but degraded upon return to the lower (20 ppm) water input. This demonstrates that higher water throughputs tend to partially restore coalescence. At this point in the test, the additive was then removed from the fuel by clay treatment and

TABLE II

TYPE OF ADDITIVE TREATMENT AFFECTS TIME TO DEACTIVATE FILTER COALESCER

Variable	Additive Concentration, ppm	Filter	Water	Gallons Through Test Pad Before Deactivation (1)
Additive W	1	C	Syn. Sea(2)	132
				150
Additive Y	12	C	Syn. Sea	202
				185
Additive W/Y	1/12	C	Syn. Sea	620
				500

(1)Deactivation defined as an 85 Filter Sidestream Sensor Rating.

(2)Synthetic Sea Water = "Sea-Rite", a simulated sea water from Lake Products Co., St. Louis, MO.

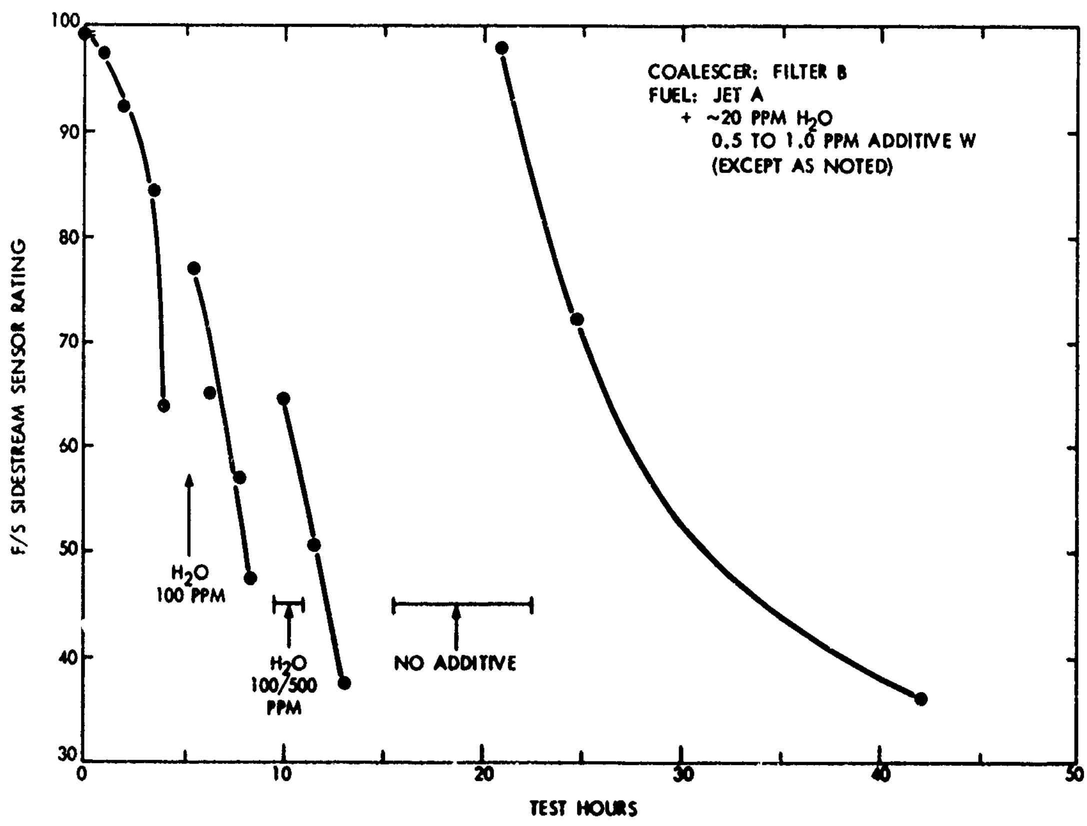

Figure 9. Effects of water and additive on F/S performance.

additive addition halted for a period of approximately five hours while the 20 ppm water injection was kept constant. The result was dramatic. Full coalescence was restored as indicated by an FSS rating of 98. Reintroduction of additive and low water (20 ppm) caused a rapid degradation of coalescence but no faster than during the initial deactivation.

Based on the results shown in Figure 9, it is apparent that surfactants which foul coalescer surfaces are at least partially water soluble and, therefore, water extractable. The polar portion of the surfactant molecule attaches to the water and in turn is deposited on the water wettable surfaces of the coalescer surfaces. Under conditions of high water levels, the surfactant concentration is low and any deposition of surfactant is flushed from the coalescer surface. When no water is present, the surfactant has no chance for deposition on the fibers and passes unhindered through the filter. However, in

the critical region of low free water levels--the very target of fueling operations--surfactant concentration is highest in the water and in turn deposition on the coalescer fibers is maximized and deactivation of these surfaces occurs at a relatively rapid rate. Ironically, the fueling systems that consistently operate at free water levels of 10-20 ppm are apt to degrade coalescer performance most rapidly.

The importance of the extractability of surfactants by water on coalescer deactivation is demonstrated in Table III and Figure 10. Figure 10 shows the relative extractability of two different jet fuel additives while Table III presents the coalescer deactivation data on four different filters. Comparing the extractability of additives, Additive W was readily water extractable while Additive Z was not. Likewise, Additive W showed a faster deactivation of coalescers than Additive Z as shown in Table III.

The above data on the effects of water and surfactants demonstrate the importance of all factors which have cumulative and reversible effects in filter-separator performance. In addition, they give greater understanding and insight into filter performance. It is therefore felt that any device to measure performance must take these factors into account--as does the Sidestream Sensor which provides a historical log of the main filter system.

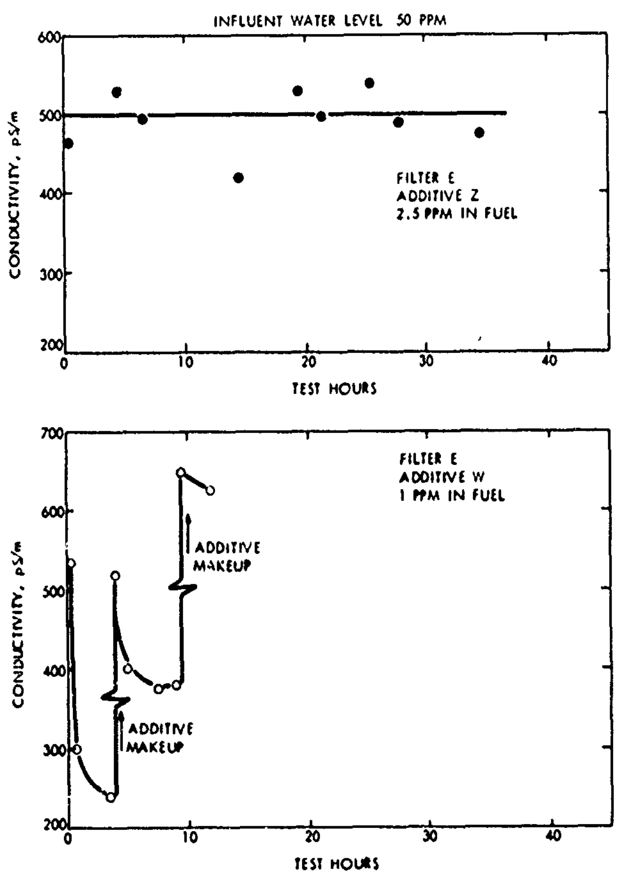

Figure 10. Relative extractability of additives from fuel by water and filter.

Correlation of FSS with Main F/S Elements

Results obtained on the Filter Sidestream Sensor in full-scale tests are given in Figure 11. Shown here is the correlation obtained between the Sidestream Sensor ratings and free water levels in a 600 gpm main F/S vessel effluent. The Sidestream Sensor ratings are turbidity readings of the Sensor effluent as measured by the Mini-Sonic Separometer while the free water levels in the main vessel effluent were measured by ASTM D 3240 with the Aqua-Glo instrument. Presented in Figure 11 are data on two commercial filters qualified against API Bulletin 1581[10] Group II (additive fuels). The open and closed circles represent data obtained during repeat runs on Filter A while the triangles represent data on Filter B. As can be seen from this figure, considerable scatter of data exists about the linear, least squares line. The correlation coefficient from a linear regression analysis of the data was calculated to be 0.94. Much of the scatter is felt to be due to the lack of precision of the methods used in the measurements - a Mini-Sonic Separometer rating by ASTM D 3602 for the Sidestream Sensor rating and a D 3240 Aqua-Glo free water reading for the effluent fuel from the main vessel. However, additional testing may prove that different filters have different correlation curves. Further work is needed to establish the existence and/or limits of any filter to filter variability.

Regardless of whether variations exist between filters, a specific Sensor rating is not intended to be used to calculate, quantitatively, main element effluent water level but rather to serve as a guide to the quality of effluent. Thus, as designed, the Sensor indicates the onset of deactivation and signals the need for element changeout to ensure continued downstream fuel quality. Based on the findings to date, a Sensor rating of 85, corresponding to a free water level greater than 15 ppm in the main F/S effluent has been selected as the end of the useful coalescer filter life and the signal for element changeout. While this level, referring to Figure 11, may seem somewhat premature for element changeout, it must be remembered that typically the onset of deactivation is followed relatively rapidly by complete deactivation as shown in Figure 5.

USE OF THE FSS AS A MONITOR OF CLAY TREATMENT

The Nature of Clay Treatment

One means of combating the effects of natural surfactants carried over from processing or picked up in transportation of jet fuels, is the clay treatment of jet fuels for surfactant removal to prevent disarming of downstream filter-separators. Fuels are often clay treated at the refinery and at different points during their transfer. Bed type clay vessels are commonly used in refineries whereas bag or canister type clay filters are in wide use at terminal or transfer facilities at the end of multiproduct handling facilities.

Three properties of clay are of major concern for jet fuels: adsorption of surface active materials from fuel to improve or protect performance of filter/separators, water tolerance (since clay filters precede coalescers and, therefore, can be subjected to high water levels), and finally, capacity of the clay. The clay

TABLE III

EFFECT OF CONDUCTIVITY ADDITIVES ON F/S PERFORMANCE - WATER COALESCENCE

ADDITIVE W VS. ADDITIVE Z

Test No.	Fuel Treatment Prior to Test	Filter(1)	API(2) Group	Additive	Conc. ppm	C.U., pS/m	Test Hours Before Effluent Water Levels Exceed Following Amounts: 15 ppm	30 ppm
F/SP79-1	Clay Treated	B	II	W	1.0	527	1.5, 3	–
F/SP79-2	Clay Treated	B	II	W	1.0	444/600	3	7
F/SP79-3	Clay Treated	E	I	W	1.0	541	1	7 1/2
F/SP79-4	Clay Treated	C	I	W	1.0	627	1	2 1/2
F/SP79-5	Clay Treated	A	II	W	1.0	428	3.5	8 1/2
New Fuel F/SP79-6	Clay Treated	E	I	Z	2.5	490	>40*	>>40
F/SP79-7	None	C	I	Z	2.5	450	25	>40
F/SP79-8	Clay Treated	B	II	Z	2.5	475	>37	>>37
F/SP79-9	None	A	II	Z	2.5	415	>35	>>35

*Hours at test end with no failure of coalescers

(1)All tests conducted at rated flow capacity (API, Class B) of element, with 50 ppm water continuously injected into filter influent.

(2)API Group I elements approved for non-additive fuels, Group II - additive (ASA-3, Corrosion Inhibitor) fuels.

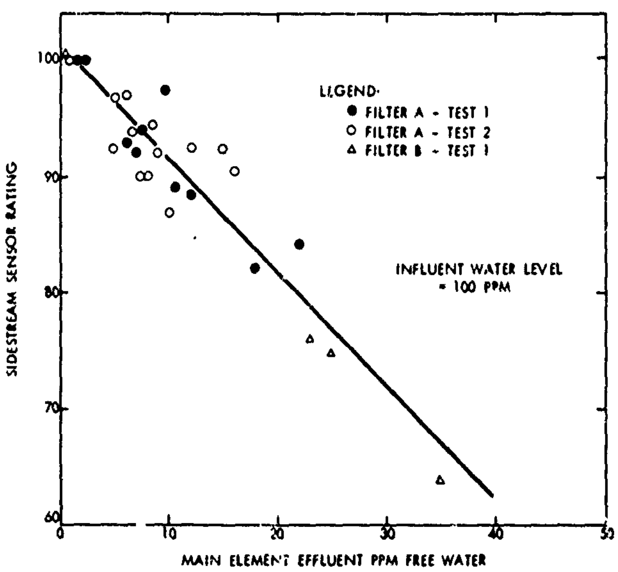

Figure 11. Filter Sidestream Sensor rating correlates with main element water level.

most widely used in the petroleum industry is an attapulgite mineral known as Attapulgus clay. Attapulgus clay is found in economic quantities in the Florida-Georgia region of the United States, India and the Soviet Union. Compared to other clays, attapulgus clay is characterized by high surface area, high sorptivity, and decolorizing power. Because of its unique three dimensional structure, Attapulgus clay does not swell when exposed to water like other clays of the same family (montmorillonite). The large surface area of Attapulgus clay is the leading factor in its high adsorptivity. The external surface area and the packing of the needle-like structure in highly porous fashion results in high adsorption power. In addition to the external surface, the intracrystalline channels also participate in adsorption of polar molecules.

The ability of clay to remove jet fuel surfactants is dependent upon the relative amounts of clay and surfactant involved and the rate of reaction between clay and surfactant. Levinspiel(9) has described this reaction rate as a function of parallel-type resistances through (1) the liquid boundary layer surrounding the clay, (2) the reacted or surfactant laden layer of clay sphere, and (3) the shrinking surface area of the unreacted core of the clay particle. The reaction rate decreases as velocity and clay particle size increase, and unreacted core size decreases.

Presently, the ASTM D 2550 Water Separometer test (WSIM) or its field counterparts - the D 3602 Mini-Sonic Separometer (MSS) and the ASTM approved Micro-Separometer

are used to monitor the efficiency of surfactant removal by clay. However, use of these instruments requires: (1) that the system be operating at the time and (2) that entering fuel contain surfactant so that surfactant removal efficiency can be measured on a concomitant downstream sample. The signal that clay is spent occurs only after entering surfactant concentration "breaks through" to the clay exit. The above instruments give no forewarning of this impending breakthrough.

Figure 12 presents an illustration of a clay treatment element and the breakthrough phenomena. As pictured, flow through a clay element is from outside-in resulting in a unit flow area as shown of diminishing area in the direction of flow through the element. Shown below the element is a diagram of surfactant concentration in the fuel as the fuel passes through the element. Curve 1 represents surfactant removal on fresh clay. Curve 2 represents mid-life of clay and Curve 3 after breakthrough has occurred. Surfactant breakthrough can occur suddenly and with little warning. This is demonstrated in typical deactivation curves for three different clays shown in Figure 13. The break in the curves indicated the breakthrough of surfactant into the clay effluent. Any method used to monitor clay performance should be capable of predicting the approaching surfactant breakthrough and end to useful clay life. The Clay Filter Sidestream Sensor was designed to provide this capability.

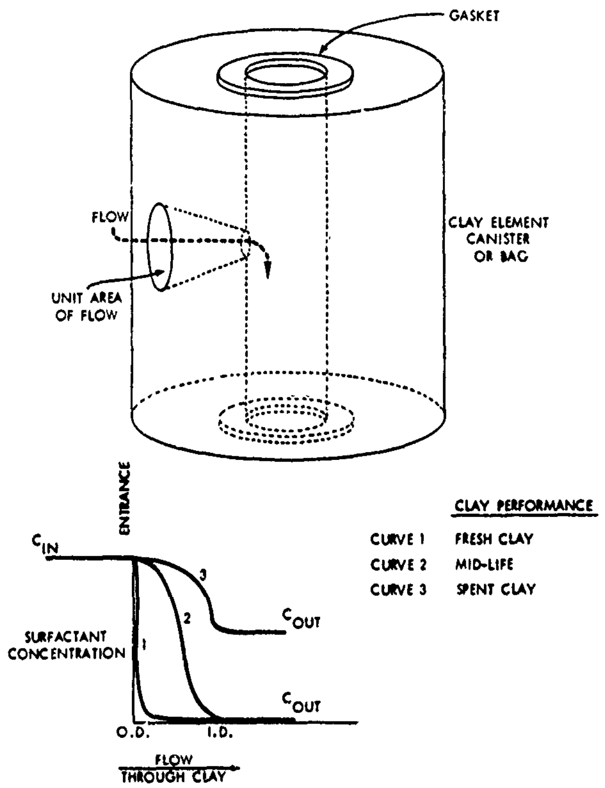

Figure 12. Flow through clay treatment element.

Construction of the Clay FSS

Like its counterpart, the F/S Sidestream Sensor, the Clay Sensor operates on a sidestream with dynamic similarity to the main clay element. The dynamic similarity between sensors and main filter is provided by maintaining geometric construction similarities of the Sensor. This is shown in Figure 14 which is a sectioned view of the clay holder. The cone section duplicates the unit flow area shown on the element in Figure 12. As with the F/S FSS, sidestream operation provides two major advantages to other techniques of clay evaluation. First, it provides a cumulative history of all factors which may have affected clay performance, and second, evaluation of the Sidestream Sensor can be independent of whether the main filter is operating or not.

Current clay performance and assessment of impending surfactant breakthrough is obtained by the technique developed to test the Clay Sensor. Periodically, the Sensor holder containing the cross section of clay element is removed from the sidestream box and tested for remaining clay activity. The Mini-Sonic Separometer (MSS) or Micro-Separometer is used for this testing. Reference fuel containing a known amount of surfactant (Additives W and Y) is passed through the Sensor at 200% of rated flow capacity. The higher flow rate provides for a reduced residence time of the surfactant containing reference fuel and thus, an earlier warning of impending surfactant breakthrough. The effluent of the reference fuel from the Sensor holder is then measured for turbidity (MSS rating) by Mini-Sonic or Micro-Separometer. The lower the MSS, the lower the remaining activity of the clay in the Sensor. (A MSS value of 90 in the Sensor effluent is used as the end point of clay life.) Because of parameter symmetry between Sensor and main elements, activity of the main system is estimated from the activity of the Sensor.

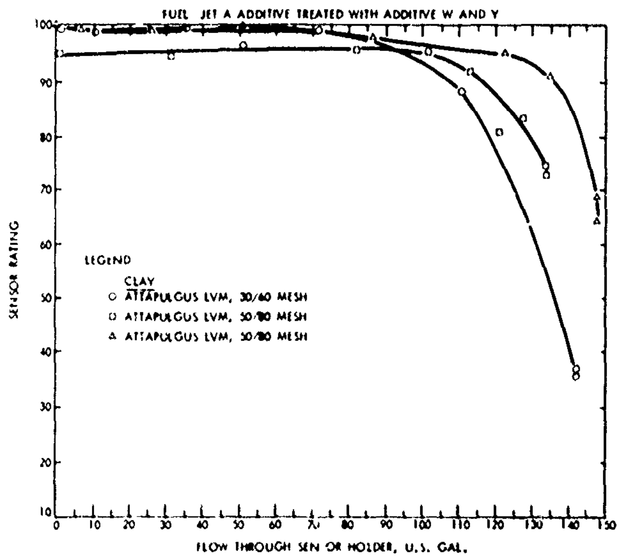

Figure 13. Cumulative clay performance.

Correlation of FSS with Main Clay Elements

Figure 15 presents a correlation between main element and Sensor on full scale equipment. For this test, a conductivity additive (W) was continuously metered into the test fuel being

recirculated through a 600 gpm vessel containing 93 clay canister elements. This additive was selected because of ease in detection by monitoring vessel effluent for electrical conductivity to determine the point of additive breakthrough of the clay. Sidestream Sensor ratings were made periodically as described previously. The data show that initially the clay was removing all the additive. A very slow increase in main element effluent surfactant concentration during the first 40 hours was found, followed by a rapid increase. The Sensor effluent showed a gradual decrease in clay activity as indicated by the Sensor Rating with an increased loss of activity occurring shortly after thirty hours. It is interesting to note that the

Figure 14. Clay Sidestream Sensor (view of holder with sectioned insert).

break in the Sensor effluent preceded the main effluent break by approximately 10 hours, thus providing forewarning of main clay deactivation. A repeat test was conducted at half the additive addition rate. Excellent agreement was obtained between tests. The total amount of additive injected into the fuel and adsorbed onto the 93 clay canister elements in each of the two tests, before an 84 Sensor Rating was obtained, was found to be within 3% (3816 cc versus 3705 cc of additives).

FIELD TESTING OF FILTER SIDESTREAM SENSOR

Measurement of clay element deactivation or detection of deactivated coalescer elements in the field is not straightforward unless the incoming fuel contains sufficient contaminant so that differences can be measured in situ on incoming and outlet streams. If contaminant is present, WSIM, Mini-Sonic or Micro-Separometer measurements provide an assessment of clay activity while such instruments as the Aqua-Glo Water Detector provide a check on coalescer performance. However, in actual field situations, the presence of contaminants are often sporadic or isolated in occurrence. As a result single element test techniques[11] are becoming more popular for filter/separator element performance checks. (Used clay elements do not lend themselves to single element tests.) These present a controlled fuel-water mix to the element under evaluation. However, there are currently only a limited number of these units available in the field and thus are often remote to the field test location. When these units are not readily available to the Sensor test location, it is necessary to rely on the

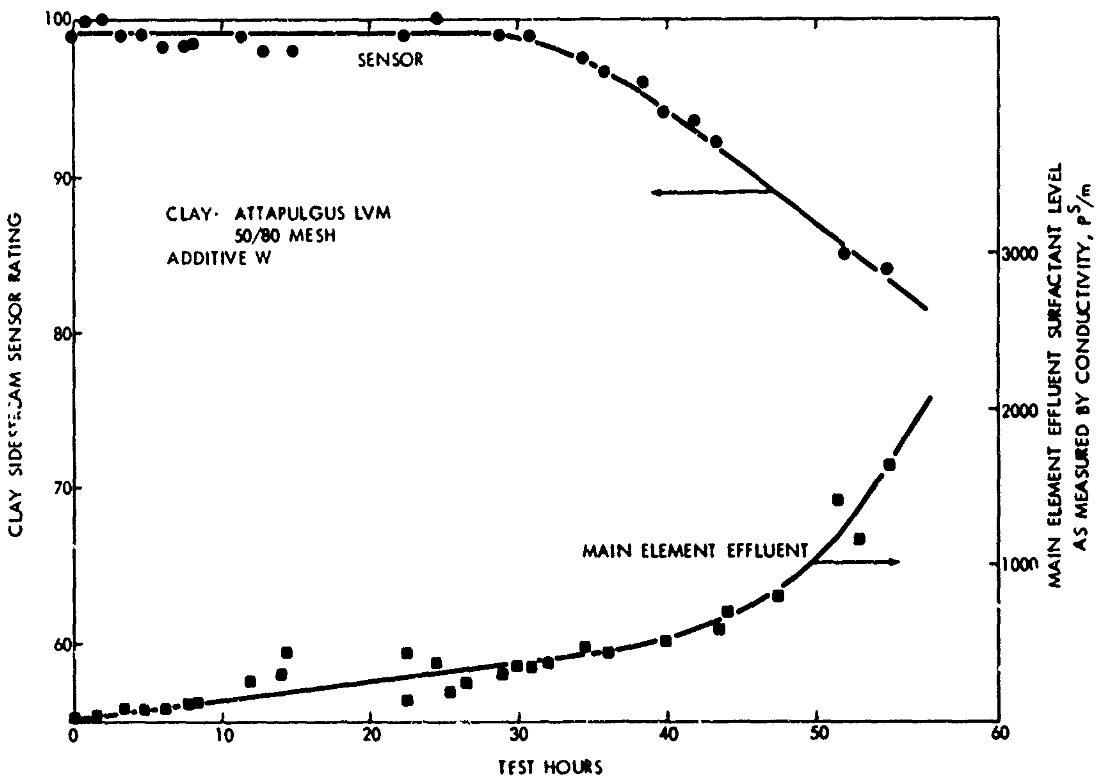

Figure 15. Clay Sidestream Sensor rating follows degradation of main clay effluent.

daily routine functional checks of the system together with Aqua-Glo or WSIM measurements for a qualitative Sensor/Main element performance check. Some of these functional checks include Millipore Color (ASTM 3830), WSIM[13], fuel water content, filter sump checks, etc.

Both clay and F/S Sidestream Sensors have been installed and are now undergoing field tests at several Exxon field locations. At two of these locations, use of the Sidestream Sensor has permitted extended service of filter/separator elements beyond the normal changeout period. Extended service is also anticipated at some of the later installations. Thus in two locations, the use of the Sensor has provided obvious economic returns of reduced operating costs. However, this excellent trouble-free filter performance in the field has not provided occurrences of filter deactivation needed to validate Sensor performance under field conditions with data obtained under controlled full-scale laboratory conditions.

At those field locations where the Sensor has been installed on clay and F/S vessels which are operating under severe conditions—such as at terminals downstream of pipelines, only a limited amount of deactivation data has been obtained to date. The data which has been obtained is presented in Table IV. At Terminal I, jet fuel product is received into tankage from a multiproduct pipeline. From tankage, the fuel is first treated by clay and then filtered by a filter/separator The clay was installed to remove surfactants and protect the F/S. Sensors were installed on both clay and F/S units. For these tests, both clay and F/S elements are changed out simultaneously when the F/S differential pressure reached 15 psi. As can be seen from Table IV, good agreement between the qualitative ratings of the Sensor and used elements was obtained. In addition, the clay treatment vessel was performing as intended by protecting the coalescence function of the F/S throughout its useful life until the F/S was changed for reasons of differential pressure.

Two incidences of F/S deactivation were encountered at Terminal II (see Table IV) when an upset occurred in the pipeline resulting in contaminant pickup by the jet fuel. The F/S elements in service at the time were disarmed and were detected by Sensor ratings. A new set of elements, along with a new Sensor, were installed in the F/S. Deactivation of the coalescer elements occurred again with the Sensor indicating a borderline or approaching deactivation. (Actually, the difference between averaged Sensor and used element ratings was only 8 units.) Since that time at Terminal II and at all other terminal locations under Sensor field tests, experience has shown that where elements are being changed out for reasons of high differential pressure due to particulate filtration, filter coalescence was still active.

Because of the limited amount of deactivation data being generated in Exxon field locations, the Filter Sidestream Sensor is being released for cooperative industry evaluation through the Coordinating Research Council (CRC) and the Institute

TABLE IV

CLAY AND F/S SIDESTREAM SENSOR FIELD DATA

Terminal I		Clay (600 gpm)(1) Activity		F/S (600 gpm)(1) Coalescence Performance	
Test No	Thruput M gal.	Sensor	Used Element	Sensor	Used Element
1	7.2	D	D	A	A
2	4.3	B	B	A	A
3	3.3	A	B	A	A
Terminal II				Sensor	Used Element
1	28.9	–	–	D	D
2	8.3	–	–	B	D

(1)Ratings on Sensor and sections of used elements placed in Sensor are based on an effluent rating by Mini-Sonic as shown below.

	F/S	Clay
A = Active	>90	>92
B = Borderline	85-90	90-92
D = Deactivation	<85	<90

of Petroleum (IP). It is hoped that this will expedite the validation of this test technique as well as establish a viable test method.

SUMMARY AND CONCLUSIONS

A small-scale monitoring system has been developed to assess the performance and end of the useful life of filter/separator and clay treatment elements. This system, called a Filter Sidestream Sensor, has undergone extensive laboratory and controlled full-scale testing. Results to date from field tests show good agreement between the Sidestream Sensor and main filter elements.

Basic studies were carried out with the Sidestream Sensor into the causes of coalescence deactivation and have shown that type, as well as amount of free water in additive treated fuel, play important roles in the speed at which deactivation of coalescers occurs. Sea water deactivates faster than tap water which in turn deactivates faster than distilled water. Small quantities (100 ppm) of free water cause fast deactivation whereas increasing amounts of water cause slower deactivation rates. When no water is present in surfactant-containing fuels, no deactivation occurs. Since this is normally the situation for F/S installed in mobile equipment, there is strong incentive to replace the current fixed time element change-out criterion with a performance criterion, using the Filter Sidestream Sensor as a means to assess performance.

Different type surfactants were found to have similar end-effect results on coalescer deactivation, but the speed at which deactivation occurs depends on both surfactant concentration and type. Water extractability was found to be an important characteristic of surfactants in determining this relative speed of coalescer deactivation. Restoration of coalescence of partially deactivated elements can be achieved by flushing the element with copious amounts of water or by removing either the water or surfactant from the fuel.

It is envisioned that the Filter Sidestream Sensor will provide a much needed tool for operations in jet fuel handling to aid in insuring delivery of clean and dry fuel. Primarily, this technique should add confidence in the assessment of day-to-day performance of filtration equipment. Secondly, it may provide a measure by which filter life may be extended in certain locations.

The Filter Sidestream Sensor is being released through the Coordinating Research Council and the Institute of Petroleum for cooperative industry testing.

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FUEL ANALYSIS - CURRENT & FUTURE

by W. G. Dukek
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The following paper was originally to be presented by Mr Dukek. Due to a scheduling error by the sponsors, Mr Dukek could not make the presentation.

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FUEL ANALYSIS - CURRENT & FUTURE

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Test methods for analyzing aviation fuels in the laboratory and in the field have undergone considerable scrutiny and some important change since this subject was presented to the 1973 Industry-Military Jet Fuel Quality Symposium[1]. This report will discuss the activities mostly in ASTM and CRC concerning (1) developments since 1973 in specifications and quality control tests (2) current active test method projects of these industry groups and (3) future testing techniques that are likely to become important as aviation fuels shift from their petroleum base to synthetic crudes.

I. DEVELOPMENTS SINCE 1973

It is mere coincidence that 1973 marked the year of the last Jet Fuel Symposium and also the start of the Arab crude embargo which began the spiral of ever-mounting crude and fuel costs and made Alternative Energy and Conservation a way of life for all of us. The crisis in fuel supply and cost had its repercussion in test methods and analytical techniques. Much more attention was paid to specifying newer methods of greater precision and to offering fuel suppliers alternative test methods to use in collecting inspection data on aviation turbine fuels. A summary of these test method improvements since 1973 appears in Table I.

If the Inspection Data Form for 1973[1] which appears as Appendix A 2 in the ASTM D1655 Specification for Aviation Turbine Fuels (Civil) is compared with the 1980 Form[2] and with the Test Methods specified for military fuels in Mil-T-5624 L as in Table I, it will be noted that the changes can be categorized in various ways:

1. more sensitivity e.g. D3242 makes possible an acidity limit of 0.015 mg KOH/g in military fuel specifications vs a limit of 0.1 mg KOH/g used in commercial fuels with method D974.
2. better precision e.g. D2382 is three times more precise than D240 for heat content of fuels.
3. more sophisticated and accurate e.g. D2622 x-ray method replaces chemical techniques for sulfur.
4. simplification and automation e.g. D3241 JFTOT test for thermal stability replaces D1660 Fuel Coker
5. new inspections and better correlations e.g. D3701 NMR method for H_2 content and the D3343 correlation technique for H_2.
6. more alternative test methods e.g. D2887 boiling range by gas chromatography as an alternative to D86 distillation.

II. SPECIFICATION TESTS[2]

Many of the test method improvements noted in Table I were discussed in the report on Aviation Test Method Developments[1] to the 1973 Jet Fuel Quality Symposium. As examples, (a) the D3241 JFTOT has now replaced the D1660 Fuel Coker test for thermal stability - a major simplication (b) the D2382 calorimetric test for heat of combustion has replaced D240 with a three fold improvement in precision (c) the D3242 acidity test has replaced D974 as ten times more sensitive (d) the D3243 Seta Flash Test has provided a superior alternative to D56 or D93 Flash Points. Beyond these examples, important new ground has been broken in adoption of modern analytical tools such as gas chromatography and NMR proton analysis.

A. Distillation by D2887 Gas Chromatography

A gas chromatographic method permits hydrocarbons to be separated in a column in the order of boiling point. With columns calibrated with known mixtures of hydrocarbons, one can obtain on a time axis a boiling range distribution of a fuel sample. In effect one attains the equivalent of a 100 plate true boiling distillation in sharp contrast to the poor fractionation of the one-plate D86 distillation test. An extensive program was conducted to correlate D2887 G.C. data with D86 results (3) and to permit military specification fuels to state limits by both methods.

However, G.C. distillation is a powerful tool for analyzing the composition of fuels and to calculate many other properties from the G.C. data. For example, D3710 is a G.C. method for boiling range distribution of gasoline fractions: the output can be used to calculate vapor pressure. JP-4 vapor pressure can be calculated in this way. Many other bulk fuel properties can be calculated from G.C. data such as gravity, viscosity and flash point. Active programs continue to be pursued to correlate G.C. data with the ultimate goal of further simplications in specification testing.

B. Hydrogen Content by Nuclear Magnetic Resonance (NMR)

Programs to eliminate redundancy in specifications and to test fuel properties that are better related to the performance of fuels in aircraft systems have been accelerated since 1973. The best example is provided by the program to redefine combustion characteristics of fuels. The differing test requirements to define the combustion characteristics of JP-4 and JP-5 between the H and L versions of Mil-T-5624 are shown in Table II.

In the 1971 version, the Smoke Point Lamp (D1322) or the Luminometer (D1740, a technique for utilizing the flame emissivity of the Smoke lamp) were alternative tests for defining combustion properties. In the 1978 version, the Luminometer has been dropped as has the Smoke-volatility Index and a hydrogen content test had become the alternative to the Smoke Lamp. The test for hydrogen allows either the new low resolution NMR Method D3701 or the D3343 correlation technique. The basis for the change was considerable combustion rig test work which confirmed that the hydrogen content of fuel was a superior measure for predicting the behavior of fuels

in engines than the earlier fuel tests. Moreover, a test for hydrogen appeared to be a better descriptor than the aromatic content of fuel as measured by the D1319 FIA test.

The older test for hydrogen content D1018 involved combustion of the fuel and measurement of released H_2O. It is a tedious and difficult procedure. In sharp contrast, the NMR technique involves placing a small sample of fuel in a strong magnetic field and applying radio frequencies to excite the spinning hydrogen atoms to higher energy levels. Energy loss in the oscillator is a measure of total number of hydrogen atoms. Fuels are compared with a reference fluid such as dodecane. Results, which are obtained in a few minutes, are extremely precise, significantly better than D1018.

III. QUALITY CONTROL TESTS

Progress has also been made in the quality control tests discussed in the 1973 Symposium report (1). The Membrane Color Rating method described in Appendix A3 of D2276 has been given separate status as D3830, the Method for Undissolved Water has been standardized as D3240 and the field method for surfactants has been standardized as D3602. Since a decision was made in 1979 to require conductivity improver additive in military JP-4 fuel, more emphasis has been needed on such quality control tests as conductivity and surfactants.

A. Conductivity Monitoring

The D2624 method is a field procedure for determining the electrical conductivity of fuels containing static dissipator additive. Since 1973, three hand-held testers and one in-line dynamic monitoring apparatus have been recognized; the Mahaik MLA Conductivity Indicator has been supplemented by the Ethyl Distillate Conductivity Meter and the Emcee Conductivity Meter, while the Staticon Conductivity Monitor has been standardized for continuous measurement. The Emcee Meter is particularly convenient, a small battery-operated portable device which can be carried in a coat pocket. For dropping the conductivity cell into a tank of fuel, a special cable is provided to extend the cell into the fluid.

The D3114 Precision Method for conductivity can also be used for testing fuels either with or without static dissipator additive but this Balsbaugh cell method is a laboratory test not readily adapted to field use. Since some conductivity additives are subject to depletion, it is important to test in the field near the point of use.

B. Field Testing for Surfactants

The D2550 Water Separometer test is specified in military fuel specifications for controlling the surfactant levels of fuel. Surfactants affect the extent to which free water droplets coalesce and can be present in fuel from natural sources, from refinery processing or from additives which have surface-active properties. Recognizing the ubiquitous nature of surfactants, military specifications establish water separation (WSIM)

ratings on base fuel before additives and on fuels after adding only corrosion inhibitor and anti-icing additive. WSIM ratings are waived on fuels containing conductivity additive since experience indicates that a combination of corrosion inhibitor and conductivity additive produces unpredictable but generally low WSIM ratings.

Because trace contaminants with surface-active properties can be picked up in the field due to pipeline or ship movements, a field test for surfactants has been developed and widely used for commercial fuels. This is the Minisonic Separometer standardized as D3602. A smaller scale and more portable version of this field test has been developed and standardized as D3948 the Micro-Separometer. In the course of its development, the ASTM Task Force discovered that the WSIM ratings between the laboratory Water Separometer D2550 and the D3948 Micro-Separometer were in excellent agreement for JP-5 and JP-8 kerosene type fuels, but there was a bias between the tests with wide-cut JP-4 fuel, the field test giving higher results according to the equation:

Field D3948 Rating = 54 + 0.45 (Lab D2550 Rating)

Method D3948 has been adopted as an alternative to D2550 by the British Government in their DERD Specifications. The Micro-Separometer apparatus is also being widely used in commercial fuel handling systems primarily to monitor fuel quality and assess the need for clay filtering to remove surface-active contaminants. The role of this device in testing coalescer cells associated with the filter sidestream sensor device under CRC evaluation is discussed in a subsequent section.

IV. CURRENT PROJECTS INVOLVING FUEL ANALYSIS

A. ASTM (and CRC) Activities

Four programs currently being pursued by Task Forces of ASTM's Technical Division J on Aviation Fuels involve fuel evaluations by new analytical techniques:

- combustion characteristics (also CRC)
- low temperature flow (also CRC)
- additive compatibility
- quality control testing handbook

1. Combustion Characteristics of Fuel

The Task Force is attempting to determine for commercial fuel the hydrogen content that is equivalent in combustion behavior to fuels presently described by the D 1319 aromatics test by FIA, the D1740 Luminometer, the D1322 Smoke Point test and the D1840 U.V. adsorption test for naphthalenes. Assistance from the CRC has been sought in analyzing engine and rig data to answer this question. None of the laboratory methods currently used to describe the combustion characteristics of fuels matches the hydrogen content analysis by D3701 NMR in precision or sophistication.

The footnotes to the D1655 Fuel Specification gave waivers to the fuel suppliers to ship fuel in the 20-25% aromatic range and the 18 to 19 Smoke Point range and at the same time established a reporting system for batches of waiver fuel. (A similar reporting program is conducted by IATA for foreign fuels.) These systems permit the accumulation of quality data on the aromatic content and Smoke Point ratings of fuels for the benefit of users. Analysis of long term trends in fuel quality provides a basis upon which engine effects can be assessed.

2. Low Temperature Flow

While a CRC Group is presently concerned with examining the relation of fuel properties such as freezing point and pour point to the behavior of fuels at low temperature in simulated aircraft tanks, an ASTM Task Force is evaluating a "black box" device called the Seta Point Detector to determine if this "quickie" test yields data equivalent to fuel properties such as freezing point, pour point, cloud point, etc. The Detector was designed for automatic operation in the field and, if successful, could become a useful quality control tool to assess the low temperature properties of fuel samples from aircraft, airports or terminals. It has also been suggested as a useful test for distillates such as diesel fuel or furnace oil which must flow at low temperatures.

3. Additive Compatibility

Before additives proposed for use in aviation turbine fuels can be approved in ASTM specifications, data must be provided not only on the efficiency of the additive but its compatibility with other additives and with aircraft fuel systems. A Task Force is presently standardizing a series of procedures for additive manufacturers to use to establish compatibility with other additives and with fuel system components such as sealants, coatings, substrates and elastomers. The procedures involve application of specification and non-specification tests to fuels containing additives and also specialized tests on specimens of components exposed at accelerated temperatures for long duration to additive containing fuels.

4. Quality Control Testing Handbook

In the distribution system between refineries and airports, aviation fuels are exposed to many opportunities to pick up contaminants. Quality control testing of fuel is practiced at various points in this distribution system by fuel suppliers, by pipeline companies, by users such as airlines and by third parties which handle fuel at airports on behalf of airlines or airport authorities. To provide guidance to these non-suppliers on techniques for quality control testing, a Task Force is preparing a Handbook of these techniques intended to become a special ASTM publication.

B. Other CRC Activities

Four programs beyond the two on Combustion and Low Temperature Flow alluded to above are active with CRC Groups. Some of these programs involve investigations that may result in new analvtical techniques for fuel or filter media:

- lubricity evaluation
- filter electrostatic charging
- water/fuel separation monitoring
- updating the CRC Fuel Handbook

1. Fuel Lubricity Test Development

Persistent but sporadic field problems with short-lived fuel pumps or sticking fuel controls testify to the fact that some fuels lack natural boundary lubricants to form films on rubbing surfaces due to the type of refining employed. Corrosion inhibitors form films and act as lubricity agents but most commercial fuels lack this additive. The Ball-on-Cylinder (BOC) wear test has proved to be excellent in detecting differences in the lubricating properties of fuels as well as the presence of lubricity agents. Manufacturers of engine components such as pumps, controls, metering valves etc. find the BOC valuable to monitor calibration test fluids.

The CRC Group has isolated certain factors in equipment and procedure to improve the precision of the BOC test and intends to pursue them until the analytical technique is ready for publication.

2. Filter Electrostatic Charging

A rig procedure for evaluating the electrostatic charging tendency of filter elements was standardized by the CRC Filter Charging Group and verified against field data. One outgrowth of that program was a requirement for a small scale laboratory procedure to check charging tendency of fuels and filter media in a standardized method. A procedure for separator media called the Mini-Static Test (MST) has been developed and development of a similar technique for coalescer media is currently underway.

3. Water/Fuel Separation Monitoring

Clay filters and filter-separators are widely used in fuel handling systems from refinery to aircraft to remove surfactants, to coalesce free water and to remove particulates from fuel but these ground systems can become ineffective or disarmed. The CRC Water/Fuel Separator Group examined various tests for fuel contaminants and concluded that none could adequately predict filter performance. However, two monitoring procedures of ground systems are being investigated for assessing the effect of fuel contaminants on filters. The Delta time test (4) is adopted to the standard membrane sampling technique that is described in D2276 while the Sidestream Sensor employs a test cell that accumulates contaminants at the same rate as full scale filters and then employs the D 3948 Microseparometer procedure to evaluate the test cell (5). Both monitoring procedures are currently under field test.

4. CRC Fuel Handbook

The CRC Fuel Handbook of 1967 (6) is being updated by a special group. This compendium of fuel properties provides data useful to fuel system designers on many properties which are not necessarily used in specification testing. For example, data on thermal expansion, viscosity-

temperature changes, surface tension, vapor pressure, thermal conductivity, enthalpy, flammability limits, gas and water solubility and compressibility represent just some of the useful properties in this Handbook which are needed by fuel system designers.

V. FUTURE ANALYSES OF FUELS

The methods being used or developed in R&D programs to analyze fuels for application to future engines and aircraft may evolve into new specification tests or advanced analytical methods in the future. While it is difficult to predict this evolution, the current R&D programs suggest four categories of analysis:

- improved fuel characterization
- new oxidation stability techniques
- better correlations from compositional data
- new field monitoring tests

A. Characterization of Fuels

Development of advanced combustors that will be suitable for a wide variety of aviation fuels including heavier materials similar to diesel fuel suggests the need for more detailed knowledge of the quantity and molecular structure of hydrocarbons. A CRC Fuel Panel of the Combustion Group recommended a series of tests to employ an experimental fuels to characterize them completely. A list of these tests appears in Table III.

It should be noted that the Panel endorsed the use of Mass Spectrometer and the C13 NMR Analyzer to identify the structure of more complicated molecules such as substituted multi-ring aromatics; these compounds are apt to be critical under combustion conditions but are not assessed correctly by current tests such as the D1319 Fluorescent Indicator Absorption technique.

B. New Oxidation Stability Technique

There is concern that the present technique for assessing thermal stability of fuels (D3241 and JFTOT)may not be adequate for future aircraft and engines. Active R&D programs are examining the oxidation stability and deposit forming tendency of fuels under various environments such as the prevaporizing section of a combustor, the fuel injector flow divider valve and nozzle, the inlet manifold and the fuel/oil heat exchanger. One modification of D3241 has been developed by CRC (7) to provide an integral preheater to simulate the heated tank environment of a supersonic transport.

Other programs to improve deposit assessment in the D3241 JFTOT are being pursued. For example, a combustion technique on JFTOT tubes is being developed to assess deposits in terms of total carbon instead of light reflectance.

C. Improved Correlations

Present correlations for hydrogen content as a function of boiling range, density and aromatics content appear to have some weaknesses, particularly with naphthenic fuels. A similar weakness applies to correlations of net heat of combustion. Some additional correlating parameters relating to composition may permit both correlations to be improved. As indicated in an earlier section, G.C. analysis has proved a powerful tool for estimating bulk properties from boiling range distribution by gas chromatography. One can expect useful correlations to develop from a G.C. data base.

D. New Field Monitoring Tests

The need to test fuels in the field for contaminant effects will increase. The potential field uses of a "quickie" freezing point test and a monitor for filter media effectiveness has been mentioned. The Seta Flash Point D3243 may be used in the field more extensively to monitor comingled fuels. A program is under way to develop a field version of the D381 existent gum test.

VI. CONCLUSIONS

Test Method Developments since 1973 lead to these conclusions:

1. Considerable progress has been made in modernizing test methods for fuels either for specification or quality control purposes. Many new methods discussed in 1973 have now been standardized.

2. One of the most active programs involves better tests to define combustion properties. Hydrogen content has been specified by military specifications as an alternative to former combustion tests.

3. Current projects in ASTM and CRC are apt to lead to better definitions of combustion quality, low temperature flow behavior, fuel lubricity, fuel and filter charging tendencies and field monitoring of fuels and filters.

4. Special Analyses of fuels in the future are apt to derive from current R&D programs related to new engines and aircraft.

5. Correlations of bulk properties from compositional data deriving from gas chromotagraphic boiling range analyses are apt to become more important in the future.

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TABLE I

ASTM TEST METHOD IMPROVEMENTS FOR INSPECTION DATA ON AVIATION TURBINE FUELS

Property	Old Method	New Method	Reason for New Test Method
Composition			
Acidity, Total	D974	D3242	More sensitive
Sulfur, Mercaptan	D1323	D3227	Better method
Sulfur, Total	D1266/ D1552	D2622	Modern technique
Volatility			
Distillation	D86	D2887	Alternative
Flash Point	D56/D93	D3243	"
Vapor Pressure	D323	D2351	"
Combustion			
Net Heat of Comb.	D240	D2382/ D3338	More precise
Smoke - Volatility Index	D1655	--	Abolished
H_2 content	--	D1018/ D3701/ D3343	Alternatives
Stability			
Δ P/Tube Rating	D1660	D3241	More precise
Contaminants			
Filtration Time	--	(1)	
Water Separation	D2550	D3602/ D3948	Alternative
Conductivity	D2624	D3114	"

(1) Described in Mil-T-5624L

TABLE II

COMBUSTION PROPERTY TESTS ON MILITARY FUELS

	Mil T-5624 H 1971		Mil-T 5624 L 1978	
	JP-4	JP-5	JP-4	JP-5
Luminometer No. min.	60	50	--	--
or Smoke Point min.	--	19	20	19
or Smoke Volatility Index	52	--	--	--
or H_2 content min.	--	--	13.6	13.5

TABLE III

Appendix F
CRC Comb.
6/13-14/79

RECOMMENDED INSPECTION TESTS FOR COMBUSTION TEST FUELS

	ASTM Method	Remarks
A. Specification Tests		
Aromatics, vol %	D1319	
Sulfur, Total, wt %	D1266/D1552/D2622	
Distillation °C (10% increments)	D86	
Flash Point, °C	D56/D3243	
Gravity, Specific	D1298	
Viscosity @ -20°C, cSt	D445	
Viscosity @ 40°C, cSt	D445	Add Viscosity at >40°C if appropriate
Net Heat of Combustion, BTU/#	D2382	
Smoke Point	D1322	Add D1740 if Smoke Point >35 or H_2 Content >14%
Naphthalenes, vol %	D1840	
Thermal Stability Breakpoint, °C	D3241	Two or more tests using criterion of <3 color tube deposits
Existent Gum, mg/100 ml	D381	
Freezing Point, °C	D2386	
Additives		List by content
B. Other Tests		
Olefins	D1319	
H_2 Content	D3701	With both dodecane and cyclohexane calibrants
Boiling Range Distribution (G.C.)	D2887	
Particulates	D2276	Only on fuels to test engine
H_2 Content	D3228/D3431	
Trace Elements	D2788	Only on fuels to test engine
Surface Tension	D971/D2285	Only by judgment
True Vapor Pressure	(Under development)	Only by judgment
Thermal Precipitation	MIL-T-38219A	Only by judgment
C. Special Characterization Tests		
1. Fuel Composition: (Note 1)		
Mass Spectrometer	(D3239)	Mandatory
Nuclear Magnetic Resonance (High Resolution)		Mandatory
2. Physical Phenomena: (Note 2)		
Specific Heat	D2766	
Heat of Vaporization		No standard test
Thermal Conductivity	D2717	
Nozzle Electrostatic Charging Tendency		No standard test

Notes:

1. MS and NMR are research tools rather than standardized tests. A single laboratory with expertise in interpretation would be a preferable source of data.
2. Attention to these methods is suggested as a possible aid in interpreting atomization and vaporization behavior.

SPECIAL MILITARY FUELS: JP-TS, JP-7, JP-9, AND JP-10

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Special Military Fuels: JP-TS, JP-7, JP-9, and JP-10

Several Air Force aircraft and missiles have special operational requirements which preclude the use of conventional military fuels such as JP-4. One of these is the U-2 aircraft. The specification for the U-2's Thermally Stable Jet Fuel dates back to 1956. The development of the XB-70 bomber resulted in the creation of JP-6 fuel just for that aircraft. But, as went the XB-70 so went JP-6. The advent of supersonic cruise, introduced with the YF-12 and SR-71 aircraft, required the development of a special kerosene fuel to meet a flight environment considered hostile by then current standards. PF-1 fuel, later called JP-7, met those standards.

As new and different as JP-TS and JP-7 appeared to be, they were still petroleum fuels produced with standard refinery processes. It was for the Air Launched Cruise Missile that the Air Force formulated a new liquid hydrocarbon fuel based on chemical synthesis. That fuel, designated JP-9, was introduced by specification in 1977. Shortly thereafter the specification was modified to include JP-10, which is actually the principal component of JP-9.

To show the chemical differences among the fuels discussed in this paper, a short review of fuel chemistry is included. Crude petroleum is composed of literally thousands of different hydrocarbon structures - molecules containing only the elements carbon and hydrogen. Other elements found in small quantities in crude petroleum (such as sulfur) are considered impurities, and their removal is necessary to assure stability and clean combustion.

The principal broad classes of chemical structures found in petroleum and petroleum-derived fuels are the paraffins, naphthenes, and aromatics. Paraffins are characterized as either straight-chain or branched-chain hydrocarbons as exemplified by hexane and 2,2,4-trimethylpentane (commonly called *iso*-octane). Figure 1 shows the structure of these paraffins.

Fig. 1 Examples of paraffins found in petroleum.

The term naphthene is a refining industry description of cyclic paraffins such as methylcyclohexane. Aromatics are highly unsaturated cyclic hydrocarbons which contain less hydrogen than their naphthenic counterparts. Benzene is a representative aromatic compound. When

drawing the more complex organic structures, it is customary to indicate the carbon atoms as the point where a line ends or two lines come together and to disregard drawing in the hydrogen atoms (Fig. 2).

Fig. 2 Examples of a naphthene and an aromatic found in petroleum.

Because the U-2 aircraft cruises subsonically for long periods at high altitude, the fuel must have a low vapor pressure and very low freezing point. The higher fuel thermal stability requirement is based on a low fuel flow rate, which raises the fuel temperature in the aircraft fuel management system. The U-2 fuel is officially called Thermally Stable Aviation Turbine Fuel, but is more commonly known as JP-TS (with or without the dash). Another term used is TSJF for Thermally Stable Jet Fuel. A JP number has never been assigned. The first specification was dated 3 February 1956, and published as MIL-F-25524 (USAF), "Fuel, Aircraft Turbine and Jet Engine, Thermally Stable". Although the fuel was identified as thermally stable, the temperature requirements for coker performance were only 300°F preheater and 400°F filter temperature. In October 1956 the specification was revised to increase the thermal stability requirement to 500°F preheater/500°F filter temperature.

Since that date, the specification was not changed until 17 March 1970, when MIL-T-25524B (USAF), "Turbine Fuel, Aviation, Thermally Stable", was issued. Although it would appear that MIL-F-25524A (and Amendment 1) were adequate, much research and development ensued in the 13 year span prior to the issue of the B revision to clear up several problems associated with storage stability of JP-TS fuel.

Around 1960 it was evident that although the fuel was procured on-specification, it rather quickly degraded with respect to the thermal stability property. In early 1966 a major step forward in solving the thermal stability problem was taken. The thermal stability additive JFA-5, a proprietary material of DuPont, was approved for addition to JP-TS at a maximum concentration of 4 lb/1,000 bbl. At the same time, the WSIM requirement (which apparently was a contractual requirement) was deleted, since the high surfactant properties of JFA-5 severely degraded the WSIM.

The revised specification more clearly defined the distillation range and tightened the existent gum, potential gum, and mercaptan

sulfur. The thermal stability requirement was officially placed at 450/550, the use of Fuel System Icing Inhibitor (FSII) was made mandatory, corrosion inhibitors and amine antioxidants were no longer allowed, and JFA-5 was required at 3 to 4 lb/1,000 bbl. A particulate requirement was also included. A significant new requirement in the "B" revision was pre-production testing, and the satisfactory completion of a one-year storage stability test prior to approval for procurement. Amendment 1 was issued 1 July 1970 to straighten out a mis-labeling of the distillation requirement, and to tighten the particulate requirement.

Like the U-2, the SR-71 was shrouded in secrecy for many years. Many aspects are still classified, but this no longer includes identification of the fuels and lubricants used in the two aircraft. Because the SR-71 cruises supersonically, aerodynamic heating puts a great stress on the entire aircraft. Bulk fuel temperatures over 300^{o}F require a very low vapor pressure fuel, which is controlled by a high initial boiling point requirement. It is well known that a high fuel hydrogen content improves combustor performance, and for this reason the aromatic content of JP-7 is maintained below 5%. In addition, a high luminometer number restricts the naphthenic portion of the fuel.

In spite of some very stringent requirements, JP-7 is not really an exotic fuel, with special "power additives" and strange ingredients, as many people have thought. It is simply a very clean high flashpoint kerosene, with a higher than normal hydrogen content. The one minor exception is the requirement for a special lubricity additive (in place of the standard corrosion inhibitor) which imparts lubricating properties to the otherwise squeaky clean product. Like JP-TS, JP-7 has a pre-production qualification requirement.

JP-7 was originally called PF-1 (PF for Processing Fluid) when first procured for the Air Force. At that time there was no formal military specification. The first specification was issued on 17 December 1970 as MIL-T-38219, "Turbine Fuel, Low Volatility, JP-7."

As mentioned previously, the jet fuels JP-TS and JP-7 are petroleum products. The high-energy fuels, however, are chemically specific structures. Although the average molecular weights of JP-9 and JP-10 are similar to petroleum JP fuels, higher fuel density (specific gravity) results in a larger volumetric heating value (Fig. 3).

The available volumetric energy content of a fuel is normally discussed in units of Btu's per gallon. This is the lower heating value, or net heat of combustion, of the fuel. For general calculations missile range corresponds proportionately to the volumetric heating value of the fuel. There are several ways to put more energy into a unit volume of fuel; the most effective means in terms of missile fuel application is to use a liquid hydrocarbon fuel which has a specific gravity greater than conventional jet fuels. These heavier fuels are prepared from specific chemical structures - liquids containing only carbon and hydrogen which have very high ratios of carbon atoms to hydrogen atoms.

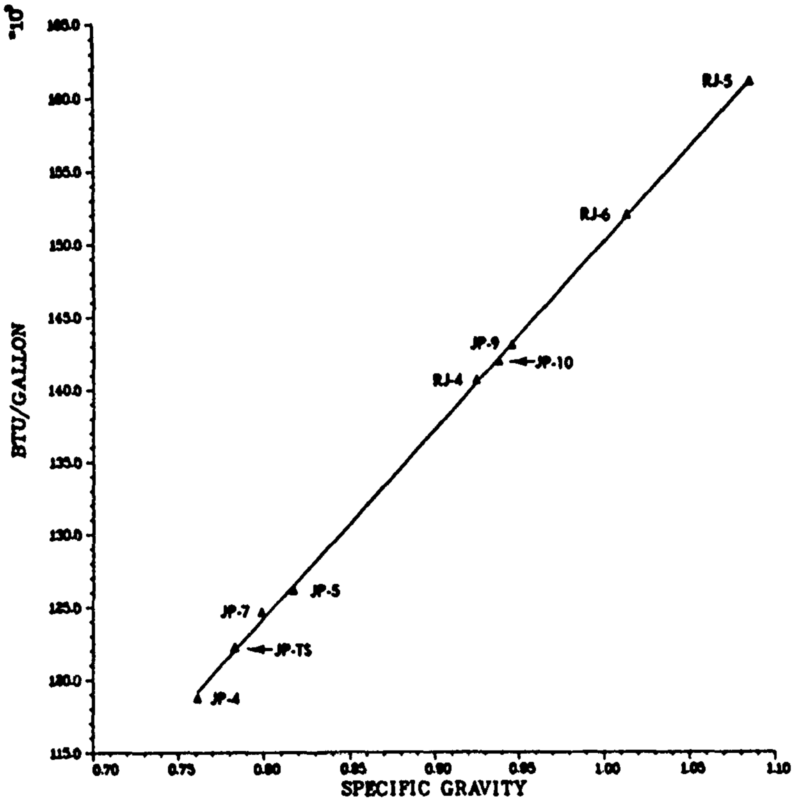

Fig. 3 Volumetric Energy

Bridged ring hydrocarbon structures (which contain high carbon-to-hydrogen ratios) increase both density and volumetric heat of combustion by the greatest amount. Naphthenic and aromatic ring structures do not offer the volumetric heating required (for example, benzene has a net heating value of only 127,000 Btu/gal, although its C:H ratio is much larger than any of the high-energy-density missile fuels.) One of the simplest bridged structures, and the one which forms the basis for all of the high-energy fuels is norbornane, chemically described as bicyclo[2.2.1]heptane (Fig. 4). The simplest fuel to describe chemically is JP-10, which has the single chemical structure *exo*-tetrahydrodi(cyclopentadiene). JP-10 is prepared by hydrogenating commercially available di(cyclopentadiene). The intermediate *endo*-structure is then isomerized (rearranged) in the presence of a catalyst to quantitatively produce pure JP-10. Figure 5 illustrates this process.

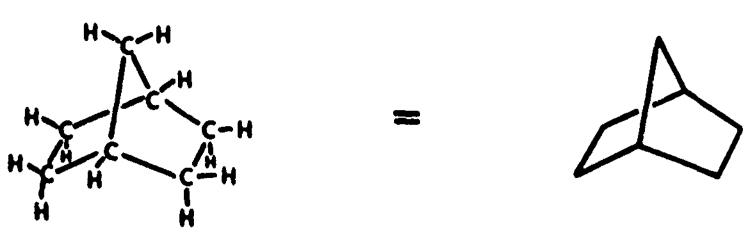

Fig. 4 Norbornane.

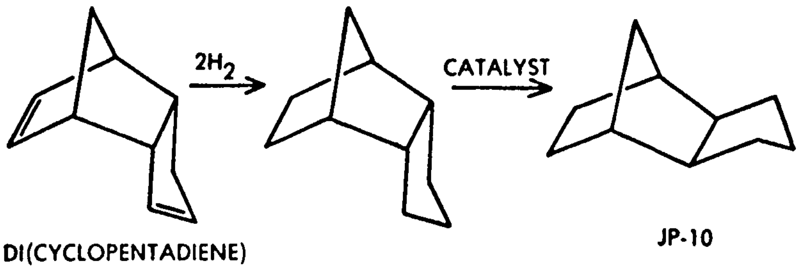

Fig. 5 Preparation of JP-10.

JP-9 had its beginnings with the Subsonic Cruise Armed Decoy (SCAD) missile program. SCAD originally was designed to fly using the Air Force standard fuel JP-4, the properties of which are well known. Although it was recognized that substituting JP-9 for JP-4 would increase the available energy by 20%, because the fuel system was originally designed for the properties of JP-4 any replacement fuel would be required to have similar properties.

It turned out that the most critical property to match was that of volatility, to assure cold-soak high altitude air start capability using a standard electrical ignition system. To meet the Air Force -65°F operational capability limit and to maintain low viscosity and high volatility, judicious selection of blending stocks was required. Shortly after the SCAD program evolved into the Air Launched Cruise Missile (ALCM) program the final formulation of JP-9 was established, and remains unchanged today. The three chemical components which make up JP-9 are stated in the specification by chemical name and weight percent required, with a two to five percent tolerance band (Table 1).

Table 1. JP-9 Fuel Components

Component	Weight %
Methylcyclohexane	10-12
JP-10	65-70
RJ-5	20-25

JP-9 is essentially a high density JP-4 substitute, offering a substantial increase in energy with modest trade-offs in other properties such as flash point and viscosity. It was mentioned earlier that JP-9 was developed to meet all of the Air Force's requirements for the air-launched cruise missile. The critical requirements were: 1) freezing point below -65°F (cold soak conditions at high altitude on a long duration mission), 2) high volatility (to enable ignition of the cold soaked fuel when the missile is launched at high altitude), 3) a viscosity of no more than 50 centistokes at -65°F (to insure fuel flow and pumpability at that temperature), 4) very high stability and cleanliness (storage life of at least 5 years, plus no detrimental effects on missile performance), and 5) no aromatic components (minimize materials compatibility problems).

The primary component of JP-9 fuel is the pure material comprising JP-10. Actually, JP-10 meets all of the preceding requirements for an ALCM fuel except for high volatility. Commercially available methylcyclohexane, the component which affords JP-9 its needed volatility, has a relatively low volumetric heating value of 120,000 Btu/gal. To offset its effect on the overall fuel heating value, the third component, a bridged ring hydrocarbon known as RJ-5, is used to bring the heating value back up to essentially that of pure JP-10. Military specification MIL-P-87107 was issued for JP-9 on 31 March 1977 and the "A" revision was published on 29 July 1977 to incorporate JP-10.

For a special purpose high energy fuel which meets the Air Force's stringent -65°F operational requirement, JP-10 has the lowest cost, is easiest to produce, has the best batch-to-batch reproducibility and excellent storage stability. Because it is a single component fuel it will not weather (lose volatile components through evaporation into the atmosphere). The flash point of JP-10 is a little lower than the Navy standard for a kerosene fuel, while its viscosity is just slightly greater than that of JP-5. Production cost of JP-10 could be in the $10 - $12 per gallon price range compared to a projected production cost of roughly $40 per gallon for JP-9. Systems which have investigated the use of JP-10 include all of the Cruise Missiles and the Navy Harpoon missile. JP-10 has been selected as the operational fuel for the development of a growth version of the Air Launched Cruise Missile.

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Pipeline Technological Developments

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These days when someone refers to technological developments, the mind immediately conjures up highly sophisticated electronic equipment design or ingeniously designed space vehicles or any one of the myriad results of advanced technology. When talking about technological developments in pipelining, we come to a much more mundane level. To be sure, there are some complex phenomena in hydraulics that arise occasionally and there are high powered computers and very involved computer programs that are used in pipeline design and operation along with some interesting instrumentation and other things; however, essentially pipelines are designed by basic hydraulics and use ordinary pumps, motors and valves to operate. Pipelines are always presented with new and unusual problems, though, because of the variety of situations and unique and variable conditions that are faced which require ingenious solutions in many instances through an involved application of technology.

Three areas will be discussed briefly that are such applications; (1) steel making progress as it affects pipelines, (2) leak detection technology, and (3) a computer program designed primarily to optimize the use of power to operate a pipeline.

Pipe Steel

The advances in manufacturing higher yield pipe steels have been very beneficial to the pipeline industry, particularly from an economical standpoint. A number of years ago pipelines were made mostly from Grade B steel with a minimum yield strength of 35,000 pounds per square inch, which required thick-walled pipe for higher operating pressures. Since steel is sold by the ton, thinner wall pipe is less expensive.

Initially, higher yield steels, Grade X-42, X-46 and X-52 were developed by increasing carbon content, the number indicating the yield strength in thousands of pounds per square inch. This gave the steel higher yield strengths but at the same time made them more brittle and difficult to weld. The steel companies, after much research, found that carbon could be replaced with so-called exotic metals, such as columbium, vanadium and titanium, to increase strength but with the added advantage of improving ductility and toughness as well, with a definite positive side effect of improving weldability. In fact, welding an X-60 or X-65 pipe today is easier than welding on the first X-52 pipe that was produced.

The cost savings for initial installation of a pipeline using X-60 pipe as opposed to Grade B for a 20-inch pipeline operating at 1440 psi breaks down as follows: 20-inch X-60 pipe would have a wall thickness of 0.344" and weigh 190 tons per mile; 20-inch Grade B pipe would have a wall thickness of 0.594" and weigh 325 tons per mile, for a difference of 135 tons per mile. At today's steel prices for pipe at approximately $600 per ton, X-60 represents a cost savings of $81,000 per mile over Grade B, in material alone. In addition, reductions are realized in welding, handling and freight costs. The thinner wall pipe also reduces consumption of natural resources, as well as paying off for the life of the pipeline in reduced energy consumption, since it takes less horsepower to move liquid or gas through the larger internal diameter pipe resulting from the thinner wall. Pipe sizes are based on outside diameter which is the same for all wall thicknesses.

Further strides have been made in the pipe industry by steel mills and pipe mills in their quality control procedures. There is more sophisticated equipment and automation used for quality control, thereby reducing the chance for human error. In fact, the Department of Transportation recently revoked a ruling that pipelines followed for years that the longitudinal weld seams in welded pipe be staggered when installed in the field to eliminate propagation of a weld seam failure through more than one joint of pipe. Following is a quote from the amendment, "This action is taken because the pipe manufacture and welding technology has advanced sufficiently to make the requirement of this section unnecessary". This, of course, reduces construction costs, since attention to the location of the longitudinal seam, which frequently requires special handling to make sure the seam is offset, is eliminated.

Leak Detection

Leak detection in the pipeline industry is as old as the industry itself; however, there are some fairly recent developments that could be classed as maturing but still rather new technologies. Two factors are involved in dealing with potential leaks; one is to try to prevent them and the other is to find them when they occur within a minimum time to reduce hazards, damage and losses as much as possible. Obviously if one can do a sufficiently good job of preventing them, there is no need to detect them. Unfortunately, the operator of a pipeline system does not have full control over all preventative measures, primarily as a result of damage by outside contractors or weather conditions. One can take all appropriate precautions about good initial pipeline location design, providing protection against external corrosion with good pipeline coatings, carefully maintaining cathodic protection, placing signs along the right-of-way indicating the location of a pipeline, providing corrosion inhibitors in the product to reduce internal corrosion

to an insignificant amount, joining "one call" organizations that publicize and provide an information service to potential excavators and even run pipe condition analyzing devices through the pipeline and there will still be an occasional leak since no system can be 100 percent effective 100 percent of the time. There are two procedures that have come into use relatively recently that I would like to discuss briefly. These are in addition to the long used methods of (1) line riding on the ground or from the air, (2) in and out volume comparisons on a periodic or continuous basis, (3) flow rate change-higher at input or lower at delivery point, and (4) static pressure monitoring.

One of the procedures is not a technological development since it is an administrative procedure named the "one call system" designed to attempt to reduce pipeline leaks by accidental punctures caused by outside excavators. A "one call system" consists of a communication center that advertises to the public for excavators to call before they dig to indicate their planned work area. The center then calls all facility owners located in the excavation area who in turn contact the excavator to review any conflicts between installed facilities and planned digging. Obviously getting the two together before digging reduces the opportunity for accidental leaks.

The other procedures for leak control that is a technological development can be described as internal pipeline inspection tools or "pigs", as they are called in the vernacular by pipeliners, which are inserted in a pipeline the same way an operator inserts scrapers. Then the "pig" is moved through the line by differential pressure either by liquid or by gas with normal pipeline pumping procedures. The only requirement for use of this inspection method is longer than normal scraper traps for launching and receiving the pigs.

The instruments in the "pig" tool utilize the magnetic flux leak-measurement technique to pick up anomalies in the pipe wall. Data produced includes a "paper pipeline" log of corrosion, welds, valves and any other metallic attachments to a pipeline. The log also includes footage of pipe the "pig" travels through, which then can be used to correlate the log information with physical pipeline longitudinal locations permitting digging up the pipeline at two or three anomolies indicated on the log and visually inspect them to "calibrate" the log. The inspection service company can then take the log to their lab and evaluate the balance of the pipeline for the severity (depth), and size of corrision pits. Once this information is accumulated, the pipeline company can use the log to accurately locate problem points on its pipeline, dig them up and make necessary repairs.

This can be used when upgrading and/or rehydrotesting a pipeline, to provide a reasonable assurance that there will be no failures during the test which reduces the amount of time and money spent locating leaks by the pressure test method.

If a pipeline is to change ownership, use of this inspection method can give a buyer very valuable information about the quality of a facility he is contemplating buying. This, of course, is much more effective than kicking the tires when purchasing an automobile.

Two other devices are used for leak detection. One is a computerized system comparing directly monitored variables in the pipeline operation with their programmed model. Variations cause appropriate alarms. The other consists of buried cables and probes with insulations that dissolve in material carried in the pipeline resulting in a short circuit setting off alarms.

Power Optimization Program

The primary purpose of SPPL's Power Optimization Program is the generation of a pump utilization schedule, given a specific pipeline product mix, hardware configuration, flow rate requirements, and batch delivery and stripping requirements that will minimize the total power cost incurred over a given operating period.

There are four categories of input data for the program: (1) problem control data, (2) line characteristics data, (3) shipment schedule data, and (4) pump utilization data.

The first category, problem control data, includes the volume of product to be delivered by the pipeline during the operating period, the length of the operating period and the time and date at which it begins, the maximum permissible electrical demand, and identification of any pumps not available for use during the operating period.

The line characteristics data category specifies the physical characteristics of the line and certain other input values that normally do not change from run to run. Included are pipe diameter and length, pump curves (digitally defined), pipeline elevation profile, maximum permissible throttling for any combination of pumping units, permissible ratios of maximum and minimum flow rates versus the average flow rate, operating pressure limits for significant pipeline locations, minimum permissible pipeline delivery rate at each location, product grade qualities such as the gravity and friction factor for each grade of product to be shipped, and electrical utility rate schedule data.

The third category of input data, shipment schedule data, specifies the volume, origin, destination, grade, sequence position and stripping requirements for each batch of product contained in the pipeline at the start of the operating period and for each batch scheduled to enter the pipeline during the period.

The fourth category, pump utilization data, allows the user to specify a certain pump utilization schedule. This category is used only when the operation of the pipeline is to be simulated. Normally, simulation is used for study purposes such as hardware expansion studies, volume growth studies, etc.

The program selects a pump utilization schedule which is a specification of pumps to be used on the occurrence of each of a certain set of line operating "events" during the operating period covered by the schedule. "Events" are abrupt changes in flow rate and/or electrical demand caused by initiation or termination of a stripping operation, changing from one delivery location to another, changing from one source point to another, or arrival at a pump station of a batch whose specific gravity differs significantly from that of the previous batch.

The procedure by which Power Op selects pump utilization is as follows: (1) determination of a set of candidate schedules from which the final schedule is to be selected; (2) calculation, for each candidate schedule, the average flow rate and expected monthly power cost, (3) selection of the one schedule from among the candidate schedules that will furnish the required average flow rate at the least expected monthly power cost.

The discharge pressure at each location is calculated as the sum of station suction pressure and net pump differential pressure, less throttling pressure required at the station to keep the pipeline pressure within allowable limits. The pressure drop across a given pipeline section at a given time is calculated as the sum of pressure losses across individual batches in the section. The Hazen - Williams formula is used for all pressure drop calculations.

In addition to an annotated listing of the program input, a wide range of results output is available for printing depending upon the options selected by the user. The "standard results" output in SPPL's version of the program includes the following:

a. An identification of each event.

b. The time of occurrence of each event.

c. The flow rate past the origin station immediately following the occurrence of the event. If a pump change is associated with the event, this flow rate is that which will result after the pump change is made.

d. An identification of the pump to be used at each station.

e. If the calculated line pressure at a controlling hill at the time of occurrence of an event does not exceed the minimum permissible line pressure at the hill, the required back pressure at the terminal or next downstream station is printed.

f. If a batch arrives at a station other than the origin, the quantity of the incoming batch already pumped at the origin is printed.

The user may also request a "detailed results" printout which includes, in addition to the "standard results" information, a printout of the location of the batches in the pipeline at a particular time or event, a pressure printout showing the net differential pressure (total pump differential pressure less station piping losses), the throttling pressure, and the discharge pressure at each location.

Other output options are: (1) a "batch status report", including (for any particular time) identification of each batch in the pipeline segment, volume of each batch, identification of origin station and delivery terminal for each batch, and total line volume between the end of the line and the trailing interface of the batch; and (2) a power consumption and cost summary report, including total pump energy consumption and electrical demand at each station during the optimization period, estimated monthly power cost at each station, and estimated monthly electrical load factor at each station.

Another important use of Power Op is "simulation", which was mentioned earlier, whereby a hardware configuration and pump utilization schedule are specified in the user's input. Through simulation a wide variety of studies can be performed. For example, it can be determined just how much volume of product a particular hardware configuration can handle, or conversely, just what hardware is required to handle a particular volume of product. This technique is commonly used for studies of future volume growth and market expansion. Different possible alternatives can thus be compared on the basis of throughput versus power cost.

One use of Power Op that might even be termed a side benefit is the comparison of actual operating results with expected results shown on the program printouts. This discovery was made almost by accident when it was noticed that the actual discharge pressure for a station and pipeline flow rate was less than it should have been according to Power Op. Subsequent investigation revealed that a check valve clapper had been wedged partially closed creating a pressure restriction. Power Op is used to check for pump wear, strainer blockages and other pressure restrictions or conditions that may be costing unnecessary power consumption or throughput loss.

As a "bottom line" for Power Op, estimates are that it is saving approximately 9% to 10% of $1.25 million monthly power bill or a recurring monthly savings in excess of $100,000. To put these savings in perspective, the total cost of development of the program to do this was approximately $200,000. Therefore, it should be plain to see why Power Op is a very important computer program and a valuable asset.

Other areas of design and operation of pipelines could be reviewed as technological developments such as piping design criteria to reduce mixing of product moving through stations and terminals, specialty instruments for batch detection, on-line computerized control of pipelines, etcetera; however, time does not permit. In summary, there are many technological developments that can be used in pipeline design and operations; however, their effectiveness in the end depends upon the pipeline operator's ingenuity in application.

NATO PIPELINE COMPLEX

PRESENTED BY

NORMAN CHORLEY

CENTRAL EUROPEAN OPERATING AGENCY

PRESENTED TO THE

INDUSTRY-MILITARY ENERGY SYMPOSIUM

21-23 OCTOBER 1980

SAN ANTONIO, TEXAS

BRIEFING TO BE GIVEN AT THE INDUSTRY/MILITARY ENERGY SYMPOSIUM AT SAN ANTONIO, TEXAS, 22ND OCTOBER, 1980

CENTRAL EUROPE PIPELINE SYSTEM (CEPS)
An integrated POL Banking System
Its History, Organization and Operation

It used to be said that an army marches on its stomach. This is no longer true. In fact an army today very seldom marches at all. Instead it is carried into the combat areas by means of some type of conveyance requiring vast quantities of liquid hydrocarbon fuels. That comparatively recent invention an airforce can only operate when it has an abundant supply of fuel at its bases. I make no mention of navies because in the Central Europe Pipeline System (CEPS) we have no missions involving naval requirements. To garner and supply the fuel needs of NATO's armies and airforces, in order that they may continue to maintain and support the Alliance's role in the Central Europe Region is the mission of CEPS. To explain as simply as possible how we go about this mission and what we have with which to perform it is the purpose of this unclassified briefing. At the outset let me give just a little history and organization.

HISTORY

When the Central Europe Operating Agency (CEOA) came into existence on 1st January, 1958, certain depots and pipeline sections had been operating since 1956/57. These consisted of 2 depots in Belgium, 2 in Holland, and 2 in Germany, plus, in this latter case, the line connecting them. (Vu 1). During 1958, there were further developments in three separate areas : the network in the Netherlands was completed ; the Bitburg - Zweibrücken loop was connected by the Metz - Zweibrücken pipeline to the US Army-owned and operated Donges - Metz pipeline ; and work was started on the Langres - Chalons lateral. During 1959, after the commissioning of most of the installations in Belgium, and in the three French divisions, the CEPS became an interconnected whole ; whilst in 1960 it was practically completed in all countries other than Germany. Between 1961 and 1965 a few on-line depots were commissioned

and the Mediterranean to Strasbourg - Kehl axis was completed. The period 1966/68 saw the start of the expansion Eastward. This has been continued since with the commissioning of forward depots and the assimilation of the old US Army pipeline and its associated depots in South West Germany into CEPS. Initially the CEPS had been designed as a single product system to handle jet fuel and to transport it by pipeline to the using bases. Replenishment was to be by tanker to ports on the French and Mediterranean coasts. During construction, however, the military authorities decided that the system should also handle ground fuels and thus it was developed as a multi-product system, handling today 4 basic military fuels, F35 (JP8), F40 (JP4), F46 (COMBATGAS), F54 (DF2).

ORGANIZATION

CEOA is governed by two committees, the Central Europe Pipeline Office (CEPO) and the Central Europe Pipeline Policy Committee (CEPPC) (Vu 2).

CEPO is a military committee chaired by a General from HQ's Allied Forces Central Europe (AFCENT) and composed of representatives of the eight nations having interests in the CEPS (Belgium, Canada, France, Germany, Luxembourg, the Netherlands, United Kingdom and the United States). It deals in particular with operational problems.

CEPPC is a politico/financial management committee, made up of representatives from each of the same nations. CEOA controls and co-ordinates the activities of the seven operating divisions to ensure that CEPS is at all times ready to fulfil its assigned missions which are (Vu 3) :

In peacetime : (i) to meet its customers' requirements,
(ii) to stock CEPS war reserves and maintain them at the proper levels.

In wartime : (i) to meet requirements,
(ii) to endeavour to maintain stocks at the appropriate levels.

The current CEPS facilities comprise (Vu 4) :

- 60 depots consisting of more than 300 semi-buried and dispersed storage tanks,

Current allocation of the storage is :

- 53 % aviation fuels,
- 47 % ground fuels.

Connecting the depots are 6 000 km of pipeline (3 780 miles) of diameter ranging from 6" to 12". All lines are buried (1 m) and there are double crossings at all major rivers. Pumping capabilities are provided by protected diesel powered pumpstations. Stand-by generator power is provided at all major installations.

CEPS entry possibilities are for instance (Vu 5) :

Ports
Sealines
Tanker berths
Refineries directly connected
Refineries indirectly connected
Barge berths
Trains
Pipelines
National depots

CEPS delivery possibilities are (Vu 6) :

Airbases
Truck fuel points
Rail fuel points
Barge berths
Pipelines
National military depots
National civil depots

If we now look at the CEPS as a whole (Vu 7), it will be seen that there are four main pipeline axes. These are :

Antwerp/Rotterdam	to	North Germany
Le Havre/Antwerp	to	West Germany
Donges/Metz	to	Southern Germany
Marseilles	to	Southern Germany

Between these main axes we can distinguish a large number of feeder and lateral pipelines. Of particular interest are those used to supply airbases, e.g. :

South of Netherlands	-	West Germany
Belgian Border	-	South West Germany

Each of the main axes are extended eastwards to one or more forward depots used to support the various Army Corps.

As was previously stated, pipeline replenishments were originally to be by tanker and this explains why the CEPS and the DMM were connected to French ports along the Mediterranean and Atlantic coasts. It soon became evident that to simplify peacetime supply and be able, in tension and war, to call on the maximum available resources on the continent, it was essential to connect refineries to the pipelines. As mentioned earlier, there already are a number of such connections, either direct or via national pipelines, and this current capability is being expanded considerably. CEPS is becoming more and more a grid system, integrated into the overall petroleum pipeline network of Western Europe.

Naturally enough the CEPS has progressively begun to show its age and the techniques that are now applied are no longer the same as those that served originally. Since 1972 it has been necessary to develop and implement a large scale restoration programme, particularly with regards to pump engines, communications, valves and cathodic protection. Other programmes are aimed at modernizing the system and it is thus that new techniques have been applied to several pipelines where pumpstations are remotely controlled. In other cases, deliveries to airbases are also automated.

Meeting customers' requirements implies planning and execution of such plans in such a way that the customers obtain (Vu 8) :

The product required	-	What ?
The quantity required	-	How much ?
The right place	-	Where ?
The right time	-	When ?
The means selected	-	How ?

CEOA, together with its operating divisions, base their planning on the customers' requests which are furnished in the format given above. As the time for execution approaches, so do the successive plans become more detailed, until the actual pumping orders are issued for actual execution. The operations involved are monitored by means of daily, weekly and monthly reports from the divisions. HQ's AFCENT are provided monthly reports on the status of stocks and of national stock credits.

In closing it is important to understand something of the quality and quantity mechanisms involved in the CEPS, where it should be remembered we are dealing with eight user nations, and four host nations. Over the years the individual national procurement specifications for the various fuels handled by the CEPS have received constant review and modification until they are now for the most part practically standard. In large measure this work of standardization has stemmed from the efforts of the NATO Military Agency for Standardization and its Fuels and Lubricants Working Parties. Today most of the major characteristics of the various national specifications for a given fuel are standard and participating nations have agreed to assign the appropriate NATO symbol to fuels procured against such specifications. Such labelling of a fuel by a NATO Symbol implies that a given fuel type manufactured to one nations specification is technically acceptable to all other nations in the Alliance. The fruits of this standaridzation obviously in the first instance are strategic, but there is another great advantage. In a civilian pipeline network it is necessary to keep each customers stock, both in storage, and in the pipelines segregated from all others, but with standard NATO Symbol Fuels it is possible to operate a common pool concept. The common CEPS pool (Vu 9),

or bank system works rather as a bank account works. Money of a certain currency (NATO SYMBOL),after counting, is deposited at one branch (ENTRY POINT), and the customer is said to have a credit of such and such an amount in such and such a currency. He may draw from and up to the value of his credit at any other branch (UPLIFT POINT). The money withdrawn is not identical to the money deposited but is of the same value and can be used exactly for the same purpose. A fee is paid to the bank for its services, which is based upon the sum of money (FUEL) involved. Monthly statements (STOCK ACCOUNTS) are furnished the client. The common pool concept makes quality control simpler than it would otherwise be, because within the network batches of fuel of the same NATO SYMBOL can be comingled in storage or in the pipeline. The only segregation necessary in such a system being that between differing NATO Symbol Fuels.

The manner of conducting Quality Control of fuels, like so many other matters within the NATO environment, is specified by NATO STANAGS or STANDARDIZATION AGREEMENTS to which all nations have subscribed.

In the Petroleum Quality Control field there are 4 STANAGS we are concerned with daily (Vu 10)you will recall my saying earlier that the majority of specification properties of any given fuel type are now standard. STANAG 1135 reviewed and updated annually, is a cross reference of national specifications accredited a NATO Symbol. For those properties of national specifications which are not standard however, or for properties which might be expected to change during transport by pipeline, STANAG 2754 entitled "FUELS TO BE INTRODUCED INTO AND DELIVERED BY THE CENTRAL EUROPE PIPELINE SYSTEM" is the bible. As its name implies it designates the types of fuel that may be transported, stored, and issued by the network, as well as the minimum quality criteria acceptable for each fuel at time of entry, and exit from the system.

STANAG 3149 "MINIMUM QUALITY SURVEILLANCE OF PETROLEUM PRODUCTS" defines the minimum measures necessary to assure quality at origin ; controls necessary to preserve and measure quality during storage and transportation, and finally precautions to ensure that quality is safeguarded at time of issue to or uplift by a customer. The fourth STANAG having a bearing on quality is STANAG 1110 "ALLOWABLE DETERIORATION LIMITS FOR NATO ARMED FORCES FUELS AND LUBRICANTS". This has little impact on the CEPS because our maximum allowable deterioration limits are spelled out by STANAG 2754, whereas the limits of 1110 apply strictly to stocks in the custody of the customer, it being recognized that once the fuels have left CEPS or elsewhere and are in the hands of the user further deterioration, particularly in long term storage can and will occur. For this reason a margin of flexibility is provided right down to the user level.

That very simply stated is the CEPS and I hope that by this very brief overview I have been able to give some impression of the vitality as well as the strategic importance of what, by any standard, is a unique pipeline network - the CEPS.

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DEVELOPEMENTS

IN

GROUND TRANSPORTATION

Gary Beatty
October 22, 1980

Good morning. My name is Gary Beatty and I am the Chief of the Transportation Division of the Defense Fuel Supply Center. I am responsible for developing emergency and operational traffic management programs for the movement of Defense fuels via all major modes of transportation worldwide.

My presentation focuses on developments in ground transportation specifically oriented to the motor and rail modes. There are many things happening in the motor and rail transportation industry today that we should be aware of. I hope to cover the important energy, economic, legislative, and operational factors affecting and shaping the motor and rail industry. I will give you my opinion on what can be expected in the future, both near and long term, and show how these trends will impact on the shipping public. Finally, I will recommend short and long term strategies designed to help you deal with these changes and reduce many of the risks that will confront you in this dynamic environment.

Chart 1
Slide 1

Transportation is big business. Twenty cents of every dollar in some way is spent on transportation. Ten percent of our work force depends on transportation industries and half of our petroleum is consumed moving people and things vital to the nation's well being. Many industries depend on the transportation industry to market their products; most significantly rubber, steel, and cement.

Chart 2
Slide 2

Until 1973 energy was relatively abundant. After the shock of the Arab oil embargo, the supply lines constricted and the motor and rail industry found themselves without sufficient fuel and very anxious about the future. Diesel fuel prices cut deeply into profits and will continue to do so. While the rest of the nation reacts by shifting to alternate energy sources, motor and

rail are dependent on petroleum and will be for the foreseeable future. ~~Conversion~~ of auto engines to diesel fuel will create more supply problems.

Chart 3 When examing the allocation of middle distillates, you can see about 50 percent is consumed by transportation. The transportation industries hope to free additional supplies as heating plants convert to solar, coal, and gas and the use of conservation methods such as raising thermostat settings and applying insulation is expanded.

Chart 4 Otherwise, as the demand for middle distillates continues to rise so will cost and supply problems.

Chart 5 The availability and reliability of sources engenders some deeply disturbing questions. As domestic production declines, we find ourselves heavily dependent on 13 foreign producing states, many of which are of dubious political stability. Political parlor games played by the Arab state members can neutralize what we would otherwise consider serious issues vital to the economic viability of our motor and rail industries. To counter act this situation, phased removal of federal price controls will stimulate domestic production. We expect 60,000 new wells to be drilled this year. The number of drilling rigs presently in use is up 30 percent over last year.

Chart 6 There are many unanswered balance of trade questions pending as we watch our petro dollars flow steadily overseas. The trade deficit has more than quadrupled since 1976. The new pricing scheme developed by OPEC will aggravate this situation. While imported oil has dropped 4.8 million barrels per day (to the lowest in five years), increased prices of petroleum have the tendency to offset the gains made by our conservation efforts and reduced consumption. This unfortunate series of events contributes to the anxiety and perplexing state of affairs faced by the motor and rail industries.

Chart 7 These factors are being expressed in economic terms. There are approximately 3.8 million miles of roads in the United States. The National Transportation Policy Study Commission projects $900 billion will be needed through the year 2000 to maintain the conditions which existed in 1975. According to a Federal Railroad Administration Study, the American railroads will have to spend between $13 and $16 million by 1985 to put their plant in good working order. New equipment is needed across the board constructed of lighter weight materials, not to mention equipment needed for highly specialized service. During a period of high interest rates and economic sluggishness, the heavy capital investment programs usually suffer, and we will eventually have to reconcile today's deferred maintenance decisions.

Chart 8 As the transportation industries grapple with present day economic issues, their concerns over interest rates and credit may be greatly influenced in the future by foreign investment in U. S. banking. Over the past ten years, foreigners have bought 90 U.S. banks; the largest of which has $16.3 billion in assets.

Chart 9 The economic casualties are beinning to emerge, such as two very large interstate motor carriers. While their reasons for folding can be explained in four basic categories, the infrastructure which interlocks these reasons is far-reaching and exceedingly complex. There are more than 100 Class I motor carriers confronted with similar problems. The rail sector has suffered several bankruptcies, and the financially plagued Auto Train Corporation, unable to meet payrolls and unable to attract foreign capital, is seeking protection under federal bankruptcy laws.

Chart 10 When we more closely examine the Class I trucking companies, we find them earning more revenue. However, there is a substantial reduction in annual percentage increase for 1979 as compared with 1978. It is also noteworthy, the length of the average haul is increasing.

Chart 11 Further examination reveals a very important fact, an overall decline in the number of Class I trucking companies in the past 13 years.

Chart 12 When we compare motor and rail, we find some basic similarities, such as increased net ton freight miles and length of average haul. Another important fact is the decrease in the amount of railroad mileage (trackage).

Chart 13 Also, the number of companies, employees, and vehicles are decreasing. One reason for an overall decrease in equipment is that greater numbers of smaller capacity equipment are being replaced with fewer numbers of larger capacity equipment.

Chart 14 The rails answer to many of the problems are to merge and develop transcontinental systems. As you can see by this chart, four companies could account for 96,600 miles or 53 percent of the total Class I rail mileage in the United States. The Chessie/Seaboard merger was approved by the ICC on September 24, 1980.

Chart 15 One of the most propitious signs of hope for the railroads is found in transportation of coal. Materialization of increased production and use can cure many of the ills which face the rail industry today.

Chart 16 Ninety percent of our energy inventory is coal. However, the most compelling threat to this tonnage is the development of coal slurry pipelines. The only existing coal slurry pipeline of any consequence is the Black Mesa system. The others reflected on this chart are proposed. Operating in favor of the railroads are the many technological and environmental barriers which stand in the way of coal slurry pipelines.

Chart 17 Many facets of motor and rail transportation have been strictly regulated for a long time. In response to the desires of the present administration the regulatory wraps are being removed layer by layer. The rail bill has now been signed into law.

Chart 18 The administration's approach is designed to let the market forces shape the industry and minimize government control on the phased down basis.

Chart 19 Reactions have ranged from laudatory to violently objectionable and carriers and shippers have been found in number on both sides of the issue.

Chart 20 One thing the motor carriers are solidly together on, and that is standardizing size and weight limits and being permitted to operate twin and triple trailer combinations.

Chart 21
Slide 3 As you can see by this chart, great variances exist in what an interstate motor carrier can haul from one state through the next. While the federal standard is set at 80,000 pounds combined weight and 65 feet overall length on interstate systems, each state has the prerogative of adopting this standard or setting their own. Arguments are very convincing on both sides. While increased loads produce greater energy and economic savings as aptly demonstrated by the carriers, the states lament over the untimely destruction and costly repair of their highways.

Chart 22	Faced with the energy, economic and legislative uncertainties, the motor and rail transportation industries have taken positive action. The motor carriers are conducting exhaustive studies to find more efficient operating techniques and coming up with substantial improvements.
Chart 23 Slide 4	About 50 percent of the horsepower required to get up to the permissible speed limit is consumed overcoming wind resistance or aerodynamics drag. To correct this power sacrifice, equipment is being redesigned taking on more aerodynamic features.
Chart 24 Slide 5	Tests have shown that cross lapping of bias ply tires produce lateral vibrations and creates more friction then radial tires. While radial tires are more expensive, there is a savings by cutting rolling resistance. Also, the carcus may be retreaded for longer life.
Chart 25	Power train and electronic speed control can produce optimum operating gear ratios and RPM settings to save fuel. On board computers can make instantaneous calculations and adjustments to set the proper conditions for reacting to climbing and descending grades and sustaining speeds on flat stretches.
Chart 26	While many drivers may extort fuel economy occurs at the high speeds, several well documented studies have conclusively demonstrated that there is an almost inverse proportional relationship between vehicle speed and fuel economy.
Chart 27 Slides 6 and 7	Individually these improvements may not appear significant, but collectively, the savings can range anywhere from 15 to 61 percent, reducing vehicle operating cost as much as $12,200 annually.

Chart 28 The railroads are making efforts to improve operating efficiency and reduce overall costs. Making up larger trains operating at slower speeds and using the right type of power configuration to save fuel. To eliminate the more fuel intensive long haul by truck, the piggyback method provides for the trailer to be placed on a railroad flat car at origin for the greater distance and then recoupled with the truck for the short haul delivery. Also, the application of computer technology simulates various operating conditions and provides the most efficient combination of power, weight, and speed. As you can see, there are several other areas being investigated by the railroads to improve operating practices.

Chart 29 An innovative method has been developed by GATX and is referred to as the tank train.

Chart 30 As illustrated here, a series of tank cars are interconnected and can be loaded or unloaded by pumps or using inert gas with positive pressure through a single connection.

Chart 31 As we have seen earlier, the number of Class I motor carriers have been decreasing through consolidations and mergers. This trend is expected to continue. Diesel fuel will be in greater demand and some states appear to be relenting on size and weight restrictions. Some carriers will agree to interchange particular hauling patterns with other carriers and equipment will be designed and retrofitted to take advantage of energy saving features. Deregulation is expected to bring intense competition and many changes in transportation rates and accessorial charges.

For the sake of long term financial stability and market planning, carriers will be amenable to provide customized service on a contract basis. Passage of the Commercial Motor Vehicle Safety Act should prove helpful in reducing the number of new or existing carriers who may be inclined to sacrifice safety for better profits. We can expect carriers to favor the longer more profitable high density routes perhaps even to the point that higher charges for short hauls will offset high density traffic with lower profit margins, and finally we will see larger, lighter, and sleeker equipment for better payloads and customized features.

Chart 32 As in the trucking industry, we will continue to see mergers in rail. The significant difference is these mergers usually result in abandonment of trackage and less profitable traffic. This leaves shippers without the rail service their business may have been built upon and force them into higher cost transportation or absorbing the cost to maintain the trackage themselves. Since rail is more energy efficient as fuel is harder to obtain and costs rise, rail will be favored. The cost incurred by the states to rebuild their highways will be passed to motor carriers in the form of highway use and fuel taxes increasing motor carrier operating cost and passed through to the shipping public in the form of increased transportation rates. Also, as the nation shifts to using more coal for power generation and synthetic fuels, the rails should benefit from substantial tonnage increases. We will see longer trains with greater emphasis on various forms of piggyback. These new sources of revenue should enable the railroads to modernize its fleet comparable to their record year of 1979 improvements. Finally, energy conservation programs will receive a greater degree of attention by railroads.

Chart 33 An additional trend we should be aware of is the shift in the nation's population. Based upon the latest statistics, the big gains will be made in the south and west. As you may have noted on our coal slurry pipeline chart, the bulk of the new pipelines run from the southwest. The motor and rail industry cognizant of this trend can be expected to dedicate capital and resources to develop these markets, perhaps at the expense of other geographical areas.

Chart 34 Shippers are going to feel the impact of deregulation, energy problems, and carrier economic conditions in three basic areas. One, the availability and traditional use of motor and rail carriers, two, what markets will benefit or suffer from changes in this dynamic environment, and three, how and where money will be spent to reduce risks and control operating procedures in the acquisition of transportation and related services.

Chart 35 Looking to the goals reported by the Department of Transportation, they appear to be designed to assure meeting the nation's transportation needs by developing a healthy transportation system.

Chart 36 Many leading authorities feel a more comprehensive coordinated effort is needed to include shippers, carriers, consumers, and special interest groups.

Chart 37 A recent GAO report has identified 11 areas which merit special attention in the 1980s.

Chart 38 They feel government involvement is of critical importance and all levels of government have a share of the responsibility.

Chart 39 I support a balanced approach and have tried to summarize what appears to be the best short and long term strategies to meet future needs. While the chart is entitled Recommendations to Shippers, it involves very close cooperation between shippers and carriers. In the short term, we must anticipate that unless movements are in high density traffic patterns, the level of service is likely to suffer and transportation rates will be disproportionately higher. Now is the time to analyze patterns and start allocating traffic to keep as many carriers participating as possible. Negotiation sessions between the shipper and carrier could result in a restructuring of carrier networks and distribution arrangements that will aid in cutting down empty mileage and improve utilization of equipment. Where substantial volumes are anticipated, volume incentive rates should be negotiated with carriers on an annual basis if possible. Where carriers have the ability to accommodate shippers, shippers should allow carriers to perform functions such as loading or unloading or developing equipment and appurtenances to improve loading and unloading operations. Care should be taken to schedule carriers equipment and clock operations to eliminate as many delays as possible. It is important to involve other levels of management in the planning functions and capitalize on their ideas. When deciding on new terminals and production locations, the number of carriers, equipment availability, and proximity to high frequency traffic patterns is of greater importance than ever before. Finally, the range of products and their intended destinations should be carefully analyzed for compatibility and possible consolidations. This type of shipment planning may contribute to negotiating volume rates as discussed above. In the long term, the full spectrum of marketing and distribution plans should include tailoring private fleets to coincide with requirements for common carriers. Traffic

should be pooled with other shippers traffic to make up large units if possible and any form of intercorporate hauling available should be investigated. On long haul traffic, the various piggyback plans should be seriously considered and the benefits of long term contracts should be fully explored. A reliable on line, real time electronic data processing system should be developed and contain rate/route data, carrier performance history and tonnage distribution data. Since many carriers have computerized their rates, shippers should pursue establishment of electronic data interchange with the carriers for building their rate data banks with automatic update capability. The greatest insurance in meeting future challenges successfully however, is through the selection and training of highly qualified traffic managers and supporting staff technicians.

In conclusion, the developmentsin ground transportation are going to be driven by economic energy legislative and operational forces much more compelling than the motor and rail industry and shipping public have faced over the last four decades. The future will belong to those innovatives and forward loading carriers and shippers who have the ability to work and plan together.

Thank You

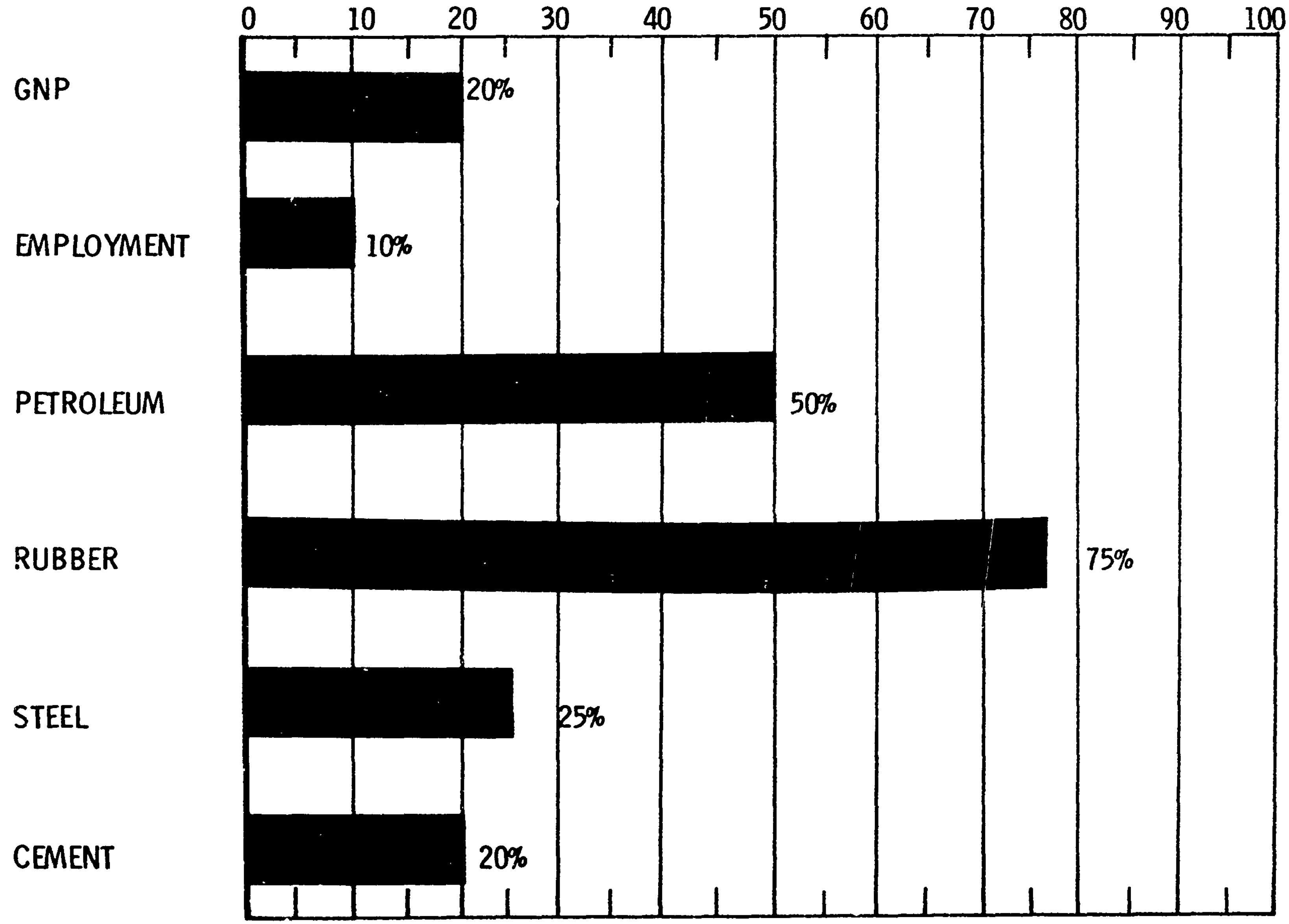
DEVELOPMENTS

IN

GROUND TRANSPORTATION

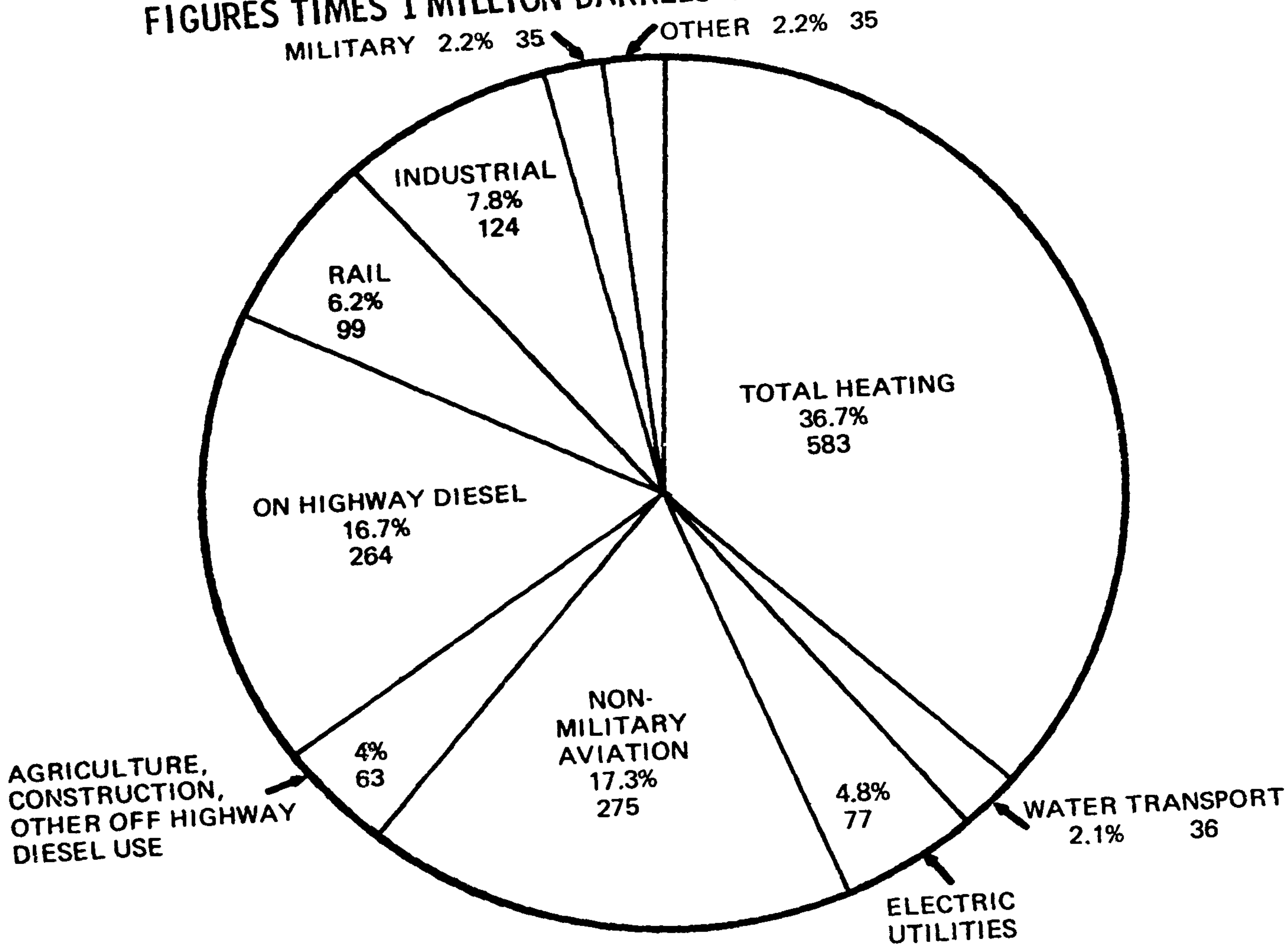
(Motor / Rail)

TRANSPORTATION STATISTICS

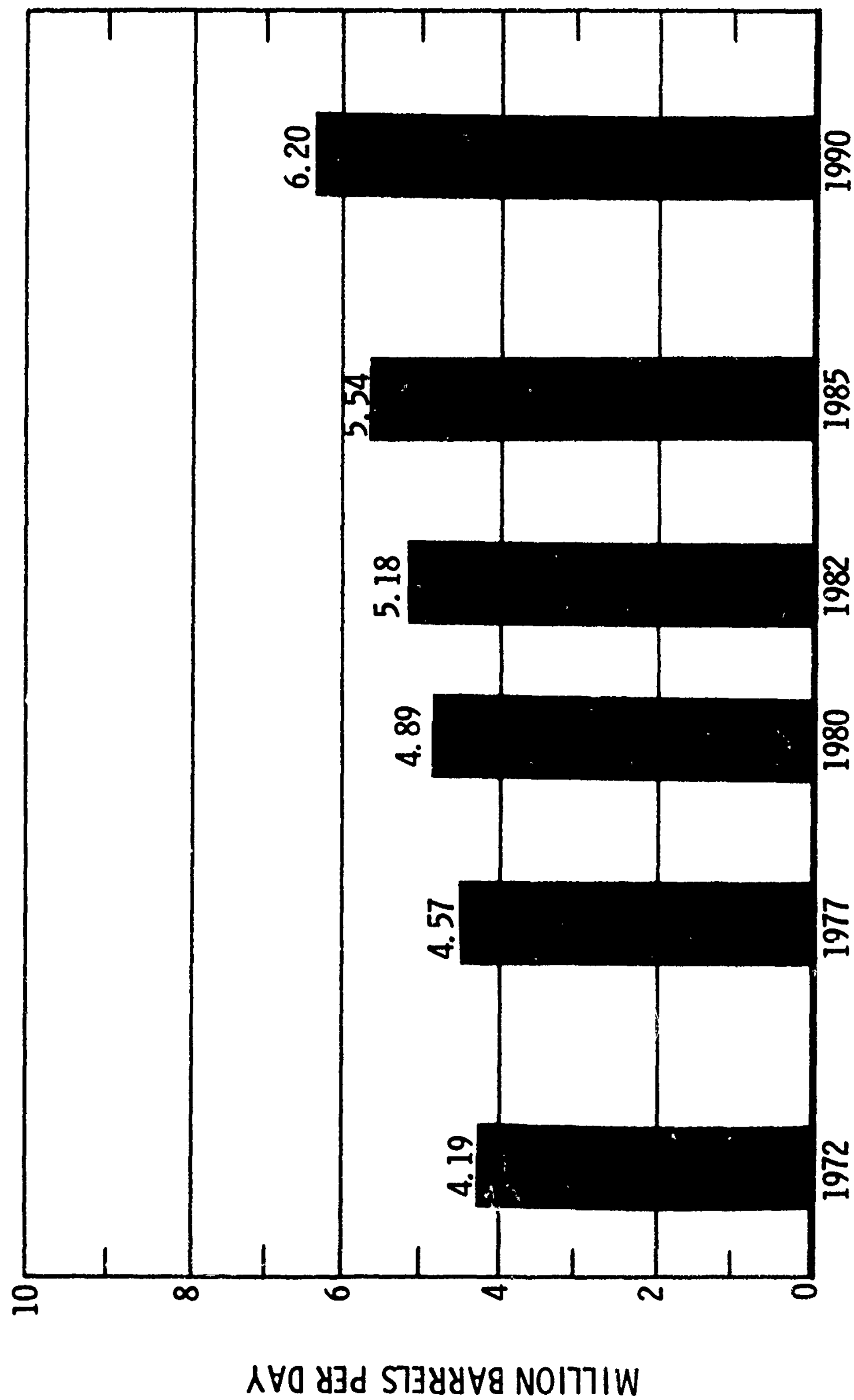


U.S. MIDDLE DISTILLATE USERS

FIGURES TIMES 1 MILLION BARRELS (1 BARREL = 42 GALLONS)

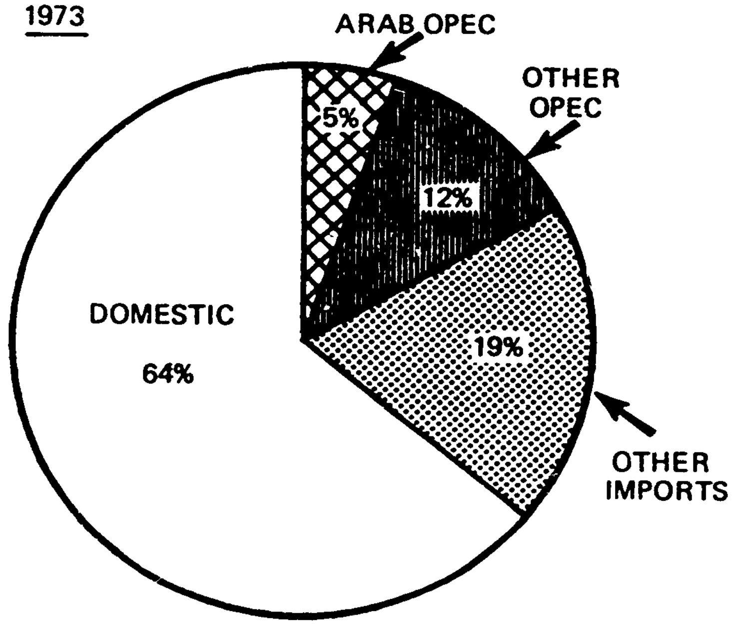


UNITED STATES MIDDLE DISTILLATE DEMAND (MMB / D)

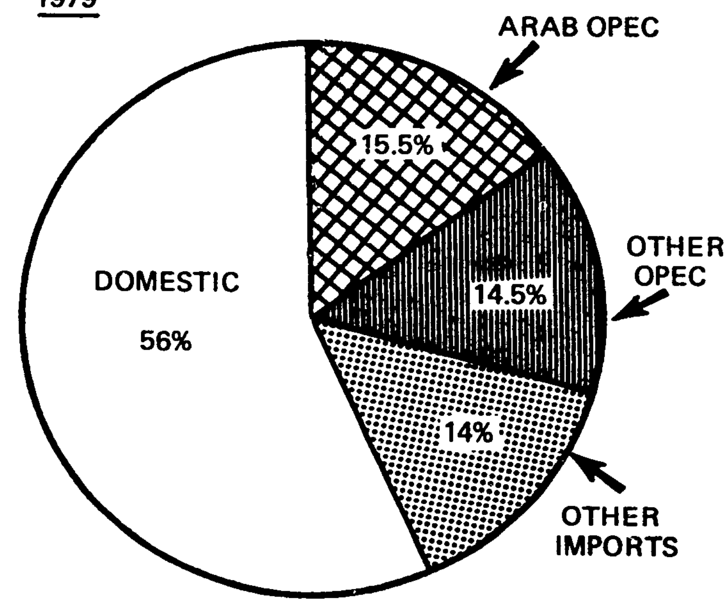


SOURCES OF PETROLEUM

1973

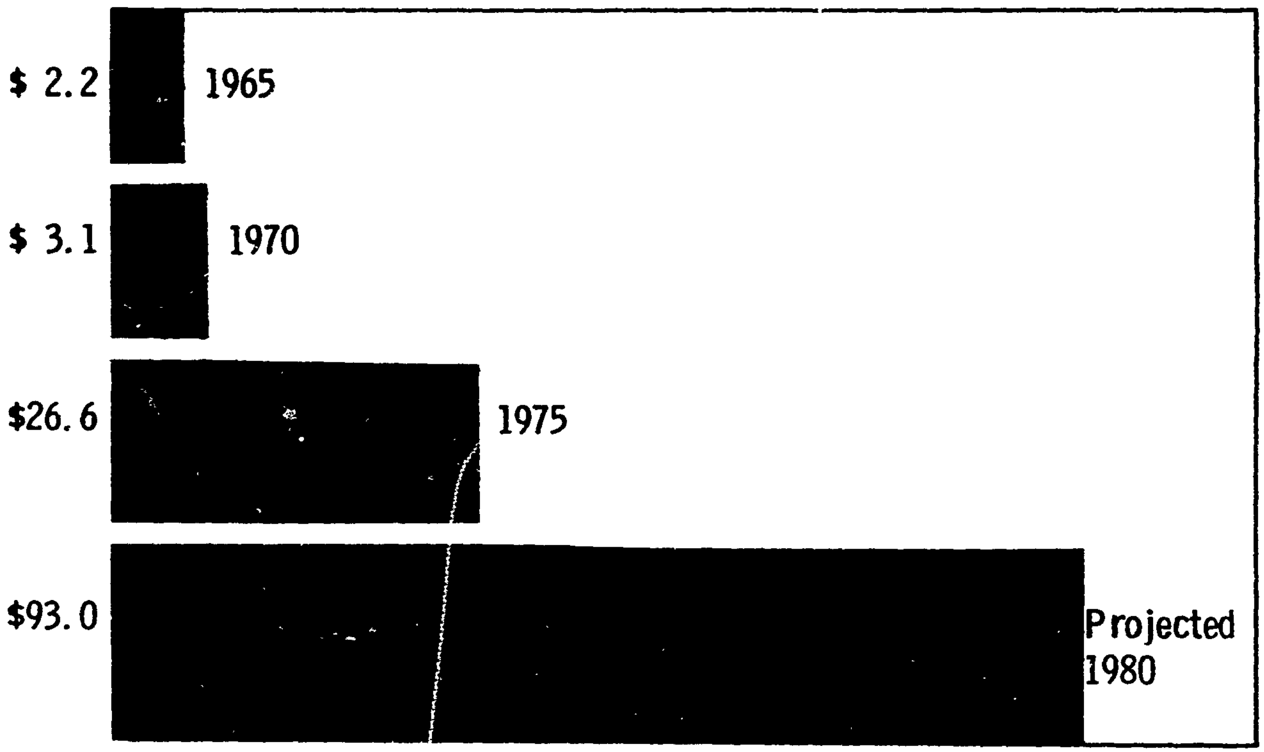


1979



DOLLARS SPENT ON IMPORTED OIL

Billion Dollars



ECONOMIC FACTORS CONFRONTING MOTOR AND RAIL INDUSTRY

- EQUIPMENT / MODERNIZATION COST
- HIGH INTEREST RATES
- DECLINE IN ECONOMY
- EFFECT OF COMPETITION

FOREIGN ACQUISITIONS OF U.S. BANKS

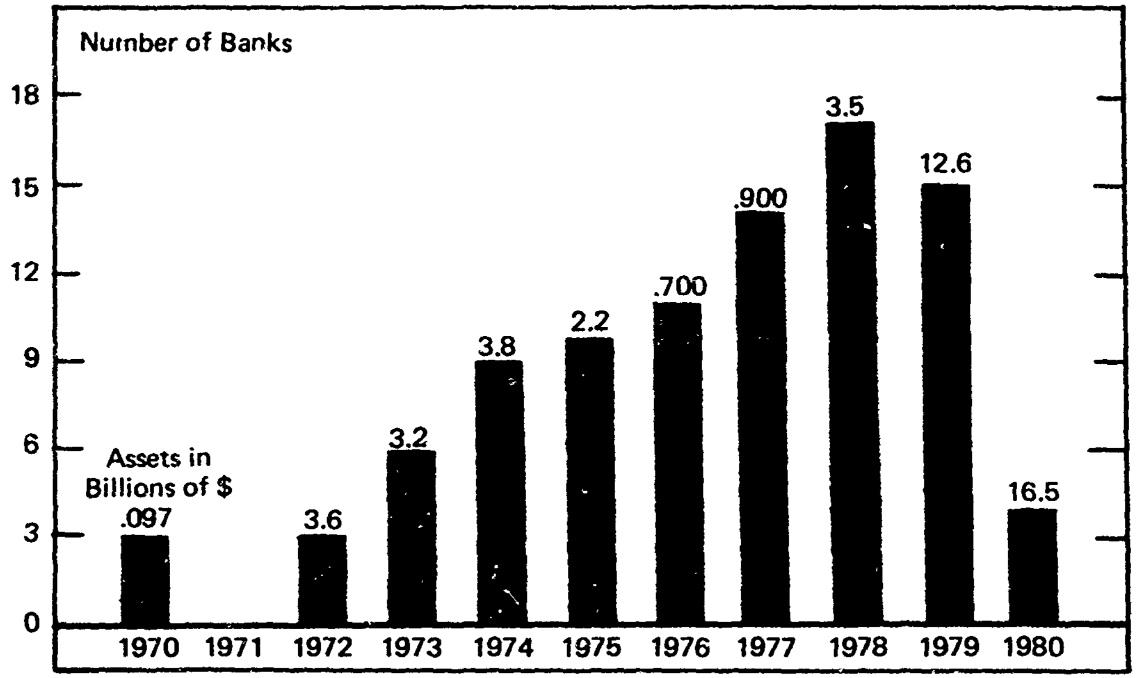


Chart represents foreign takeovers of banks by assets; there were none in 1971

ECONOMIC CASUALTIES - MOTOR CARRIERS - 1980

WILSON FREIGHT CO., CINCINNATI, OHIO (CH. 11 - BANKRUPTCY ACT)

JOHNSON MOTOR FREIGHT LINES, INC., CHARLESTON, NORTH CAROLINA (SHUT DOWN)

REASONS GIVEN:

UNCERTAINTIES OF DEREGULATION

HIGH INTEREST RATES

CLIMBING FUEL / EQUIPMENT COSTS

INADEQUATE RATE RELIEF

MORE THAN 100 CLASS I MOTOR CARRIERS EXPERENCING UNSATISFACTORY OPERATION RATIO'S.

(RATIO OF OPERATING EXPENSES TO OPERATING REVENUES.)

CLASS I TRUCKING COMPANIES (ANNUAL OPERATING REVENUES $1,000,000 PLUS)

YEAR	MOTOR CARRIER OPERATING REVENUES (MILLIONS)	NET TON MILES OR FREIGHT (MILLIONS)	VEHICLE MILES (MILLIONS)	AVERAGE HAUL (MILES)
1967	8,091	388,500	11,268	256
1977	22,520	555,000	11,145	300
1978	26,788	602,000	13,357	301
1979	28,500	610,000	13,578	495

CLASS I TRUCKING COMPANIES

	NUMBER OF COMPANIES	NUMBER OF EMPLOYEES	NUMBER OF VEHICLES
1967	1,198	424,689	16,192,776
1977	835	473,073	29,562,485
1978	885	559,347	31,702,604
*1979	870	535,000	30,400,000

*ESTIMATED

CLASS I LINE HAUL RAILROADS (ANNUAL OPERATING REVENUE $10,000,000 PLUS)

	RAILWAY OPERATING REVENUES (MILLIONS)	NET TON MILES OF FREIGHT (MILLIONS)	LINE MILEAGE	AVERAGE HAUL (MILES)
1967	10,366,000	719,498	209,826	280
1977	20,090,500	826,292	191,205	339
1978	23,279,790	880,833	190,180	358
1979	27,508,405	946,151	181,870	371

CLASS I LINE HAUL RAILROADS

	NUMBER OF COMPANIES	NUMBER OF EMPLOYEES	NUMBER OF VEHICLES
1967	76	610,191	1,523,463
1977	57	464,073	1,262,539
1978	48	471,519	1,258,283
1979	40	482,962	1,250,000

PENDING RAILROAD MERGERS

			COMBINED REVENUES / ASSETS (IN BILLIONS)	
	MILEAGE	STATUS	REVENUES	ASSETS
UNION PACIFIC-MISSOURI PACIFIC-WESTERN PACIFIC	22,900	MERGER AGREEMENT SIGNED	\$6.2	\$7.6
SANTA FE-SOUTHERN PACIFIC	25,000	MEMORANDUM OF INTENT SIGNED	\$5.2	\$8.9
CHESSIE SYSTEM-SEABOARD	26,600	MERGER HEARINGS CONCLUDED	\$4.1	\$6.8
BURLINGTON NORTHERN-ST. LOUIS SAN FRANCISCO	29,600	MERGER DELAYED BY COURT	\$3.7	\$4.9
NORFOLK & WESTERN-SOUTHERN RAILWAY	17,500	PLAN AGREED TO IN PRINCIPLE	\$2.9	\$5.7

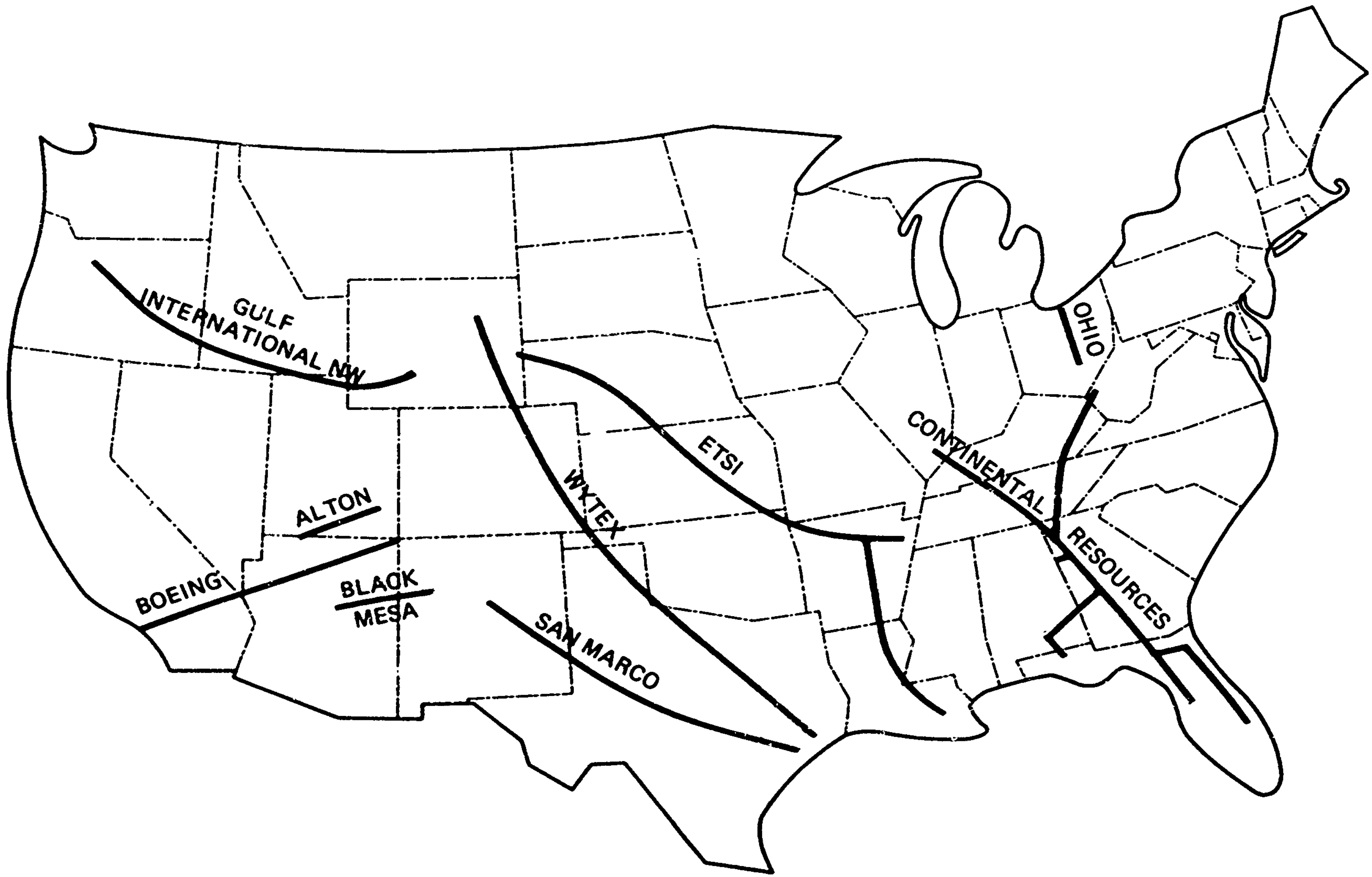
RAIL MOVEMENT OF COAL

PERCENT OF TOTAL PRODUCTION HAULED	65
PERCENT OF TOTAL RAIL TONNAGE	30
PERCENT OF GROSS REVENUE	14
PROJECTED INCREASE IN COAL PRODUCTION	60%

NOW 700 MILLION TONS

1990 OVER ONE BILLION TONS

COAL SLURRY PIPELINES



LEGISLATIVE FACTORS

- 1887 REGULATION OF RAILROADS
- 1935 REGULATION OF MOTOR CARRIERS
  - SERVICE / SCHEDULES
  - OPERATING PRACTICES
  - RATES / FARES / CHARGES
  - POLICIES
- MOTOR CARRIER ACT OF 1980 (JULY 1, 1980)
- PROPOSED RAIL DEREGULATION (HR 7235)
  - PASSED 9 SEPT (337 / 20)
  - NOW BEARS NO. S. 1946

MOTOR CARRIER ACT OF 1980 AND PROPOSED DEREGULATION OF RAILROADS

REASON: TO REDUCE UNNECESSARY REGULATION BY THE FEDERAL GOVERNMENT.

PROVISIONS:

- LIFT RESTRICTIONS ON COMMODITIES / SERVICES / ROUTES
- PROVIDE MORE PRICING FLEXIBILITY
- EASE ENTRY RIGHTS
- REDUCE REGULATORY DELAYS
- ESTABLISH MINIMUM INSURANCE LEVELS

EXPECTED BENEFITS:

- MORE ECONOMICAL, EFFICIENT OPERATIONS
- VIGOROUS PRICE COMPETITION
- IMPROVED QUALITY OF SERVICE
- ENERGY SAVINGS
- PROMOTE INDUSTRY GROWTH

INDUSTRY REACTION

FOR REGULATION:

- CONTROL OVER RATES AND SERVICES
- NON-DISCRIMINATORY TREATMENT OF SHIPPER
- POLICING THE INDUSTRY
- SAFETY AND FITNESS REQUIREMENTS

AGAINST REGULATION:

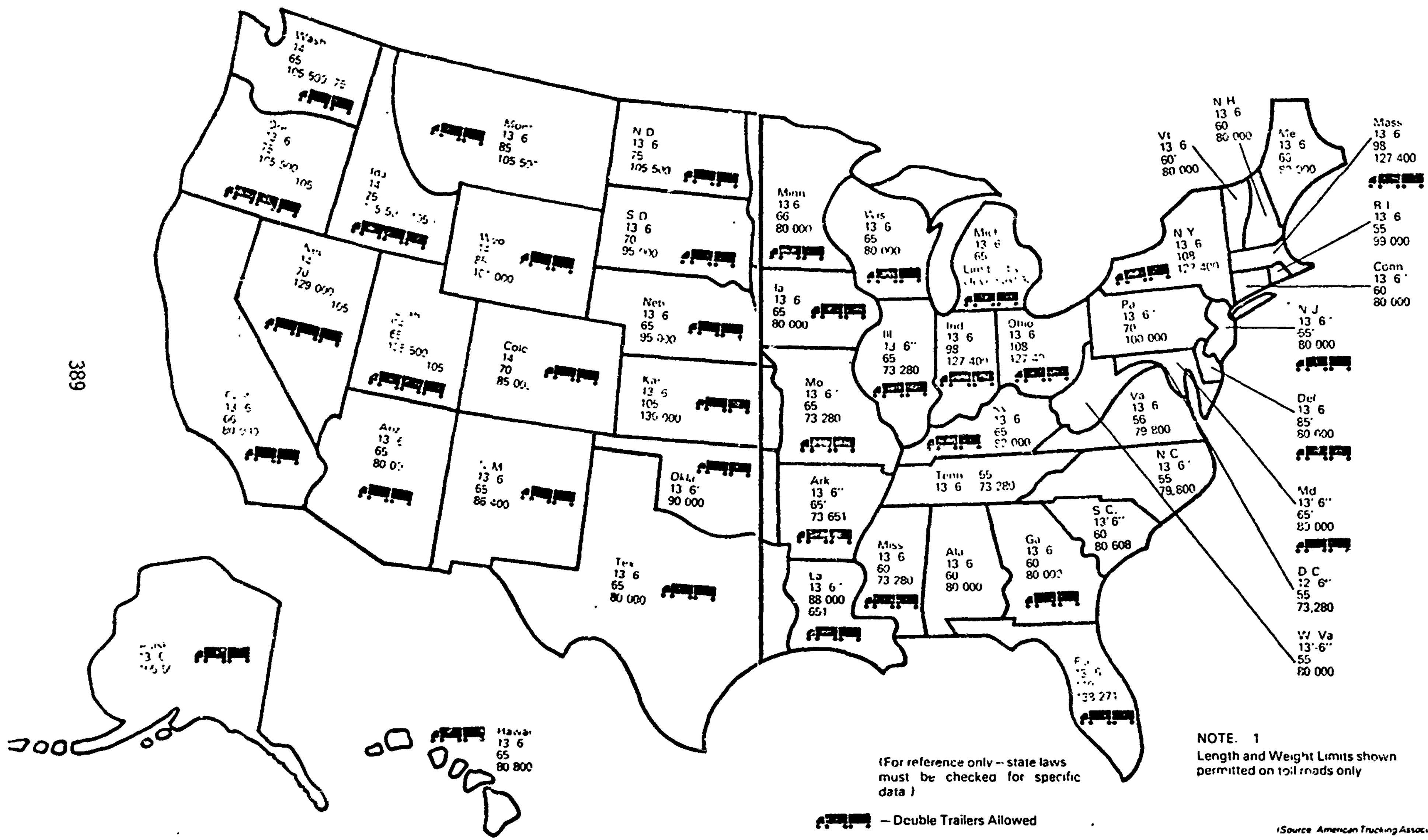
- HIGHER COST
- ENERGY WASTE
- RESTRICTING COMPETITION
- LONG HAULS
- REGULATORY BOTTLENECKS

PRINCIPLE MOTOR CARRIER PROPOSAL FOR INCREASED EFFICIENCY

STANDARDIZED SIZE AND WEIGHT LIMITS

APPROVAL FOR TWIN / TRIPLE TRAILERS

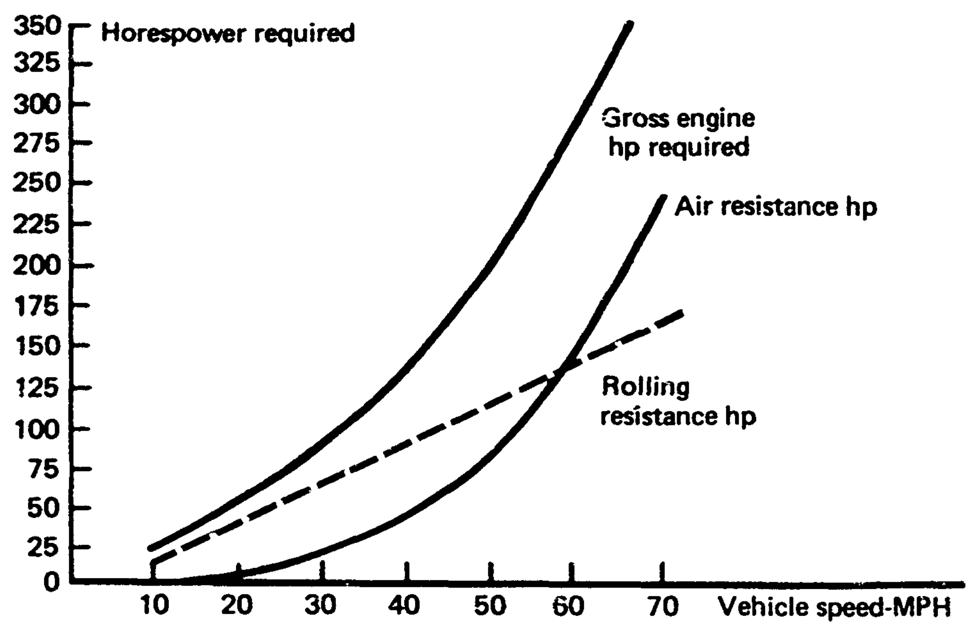
MAXIMUM STATE VEHICLE SIZE-WEIGHT LIMITS
(Height, Length, Weight or Designated Roads)



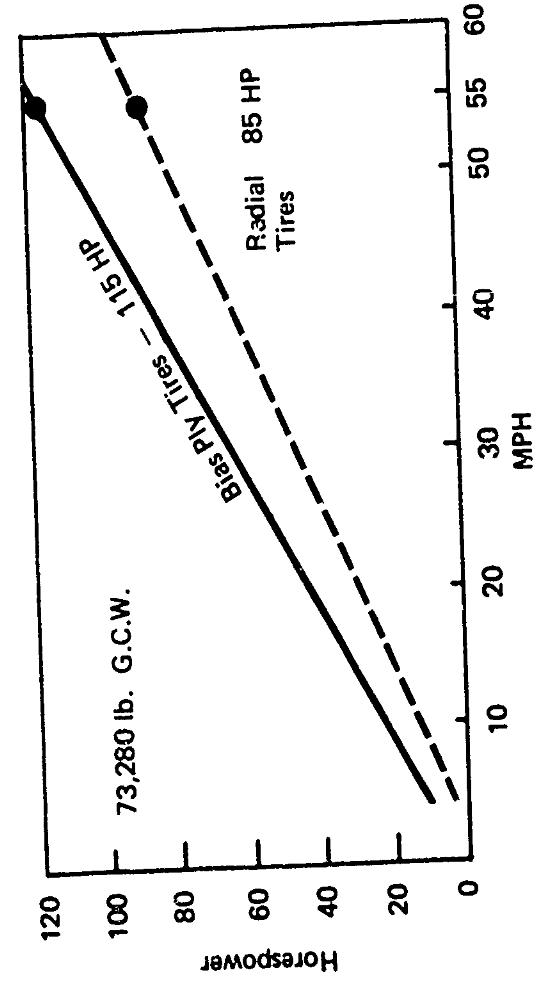
MOTOR CARRIER IMPROVEMENTS

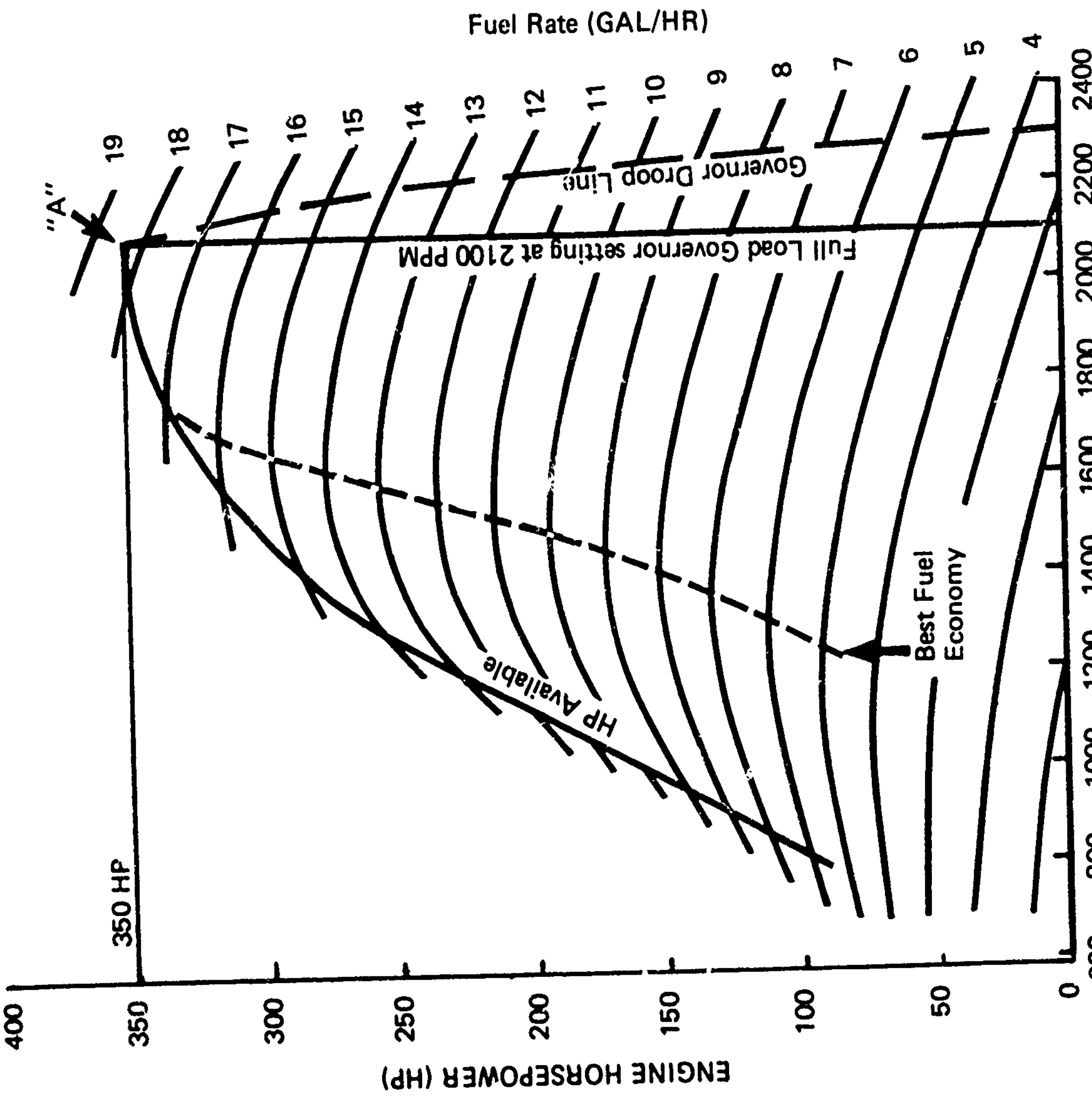
- AERODYNAMIC DESIGN
- ENGINE PERFORMANCE
- CONSTRUCTION MATERIALS / RUNNING GEAR
- ELECTRONIC CONTROLS
- MAINTENANCE PROGRAMS
- DRIVER TRAINING
- OPERATING TECHNIQUES

EFFECT OF AERODYNAMIC DRAG



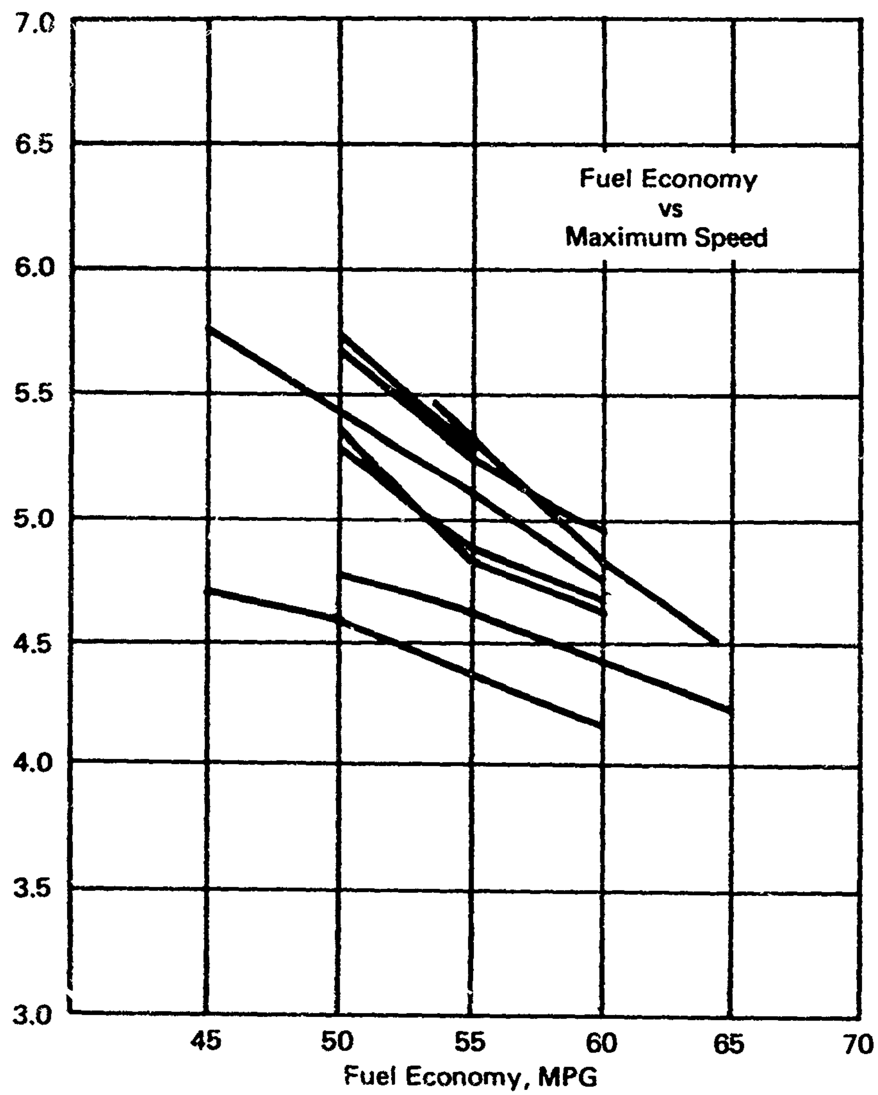
Rolling Resistance H.P. Required





Fuel Rate (GAL/HR)
"A"
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
Governor Droop Line
Full Load Governor setting at 2100 PPM
HP Available
Best Fuel Economy
350 HP
ENGINE SPEED (RPM)
600
800
1000
1200
1400
1600
1800
2000
2200
2400
ENGINE HORSEPOWER (HP)
0
50
100
150
200
250
300
350
400

SPEED - FUEL ECONOMY PAYOFF

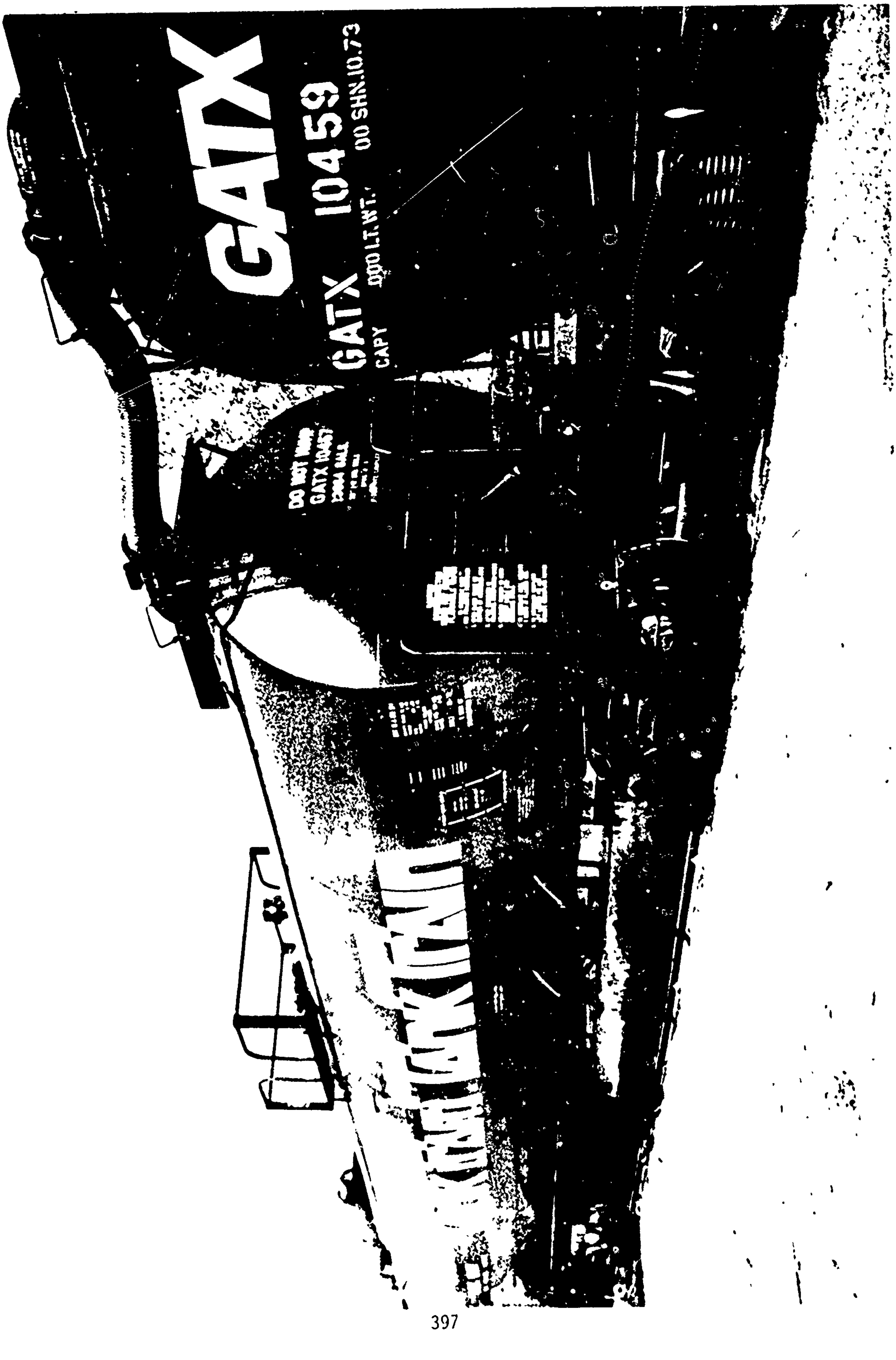


ANNUAL SAVINGS PER VEHICLE

AERODYNAMICS	4% TO 8% $800 TO $1,600
ROLLING RESISTANCE	3% TO 10% $600 TO $2,000
POWER TRAIN	2% TO 10% $400 TO $2,000
SPEED CONTROL	4% TO 20% $800 TO $4,000
VEHICLE MAINTENANCE	1% TO 3% $ 200 TO $600
DRIVING PRACTICES (EXCLUDING HIGHWAY CRUISE)	1% TO 10% $200 TO $2,000
OPERATIONAL TECHNIQUES	???

RAILROAD ENERGY IMPROVEMENTS

- UNIT TRAINS / SLOWER SPEEDS
- MORE POWERFUL, EFFICIENT LOCOMOTIVES / SLAVE LOCOMOTIVES
- EXPAND PIGGYBACK
- TRAIN PERFORMANCE CALCULATOR COMPUTER PROGRAM (OPTIMUM MIX OF POWER, WEIGHT, SPEED)
- IMPROVED OPERATING PRACTICES
  - RUN-THROUGH TRAINS (AVOID CLASSIFICATION YARDS)
  - AUTOMATIC FUEL DEVICES
  - DUMPERS (ELIMINATES UNCOUPLING)
  - HIGH SPEED LOAD / UNLOAD WITH CAR IN MOTION


GATX
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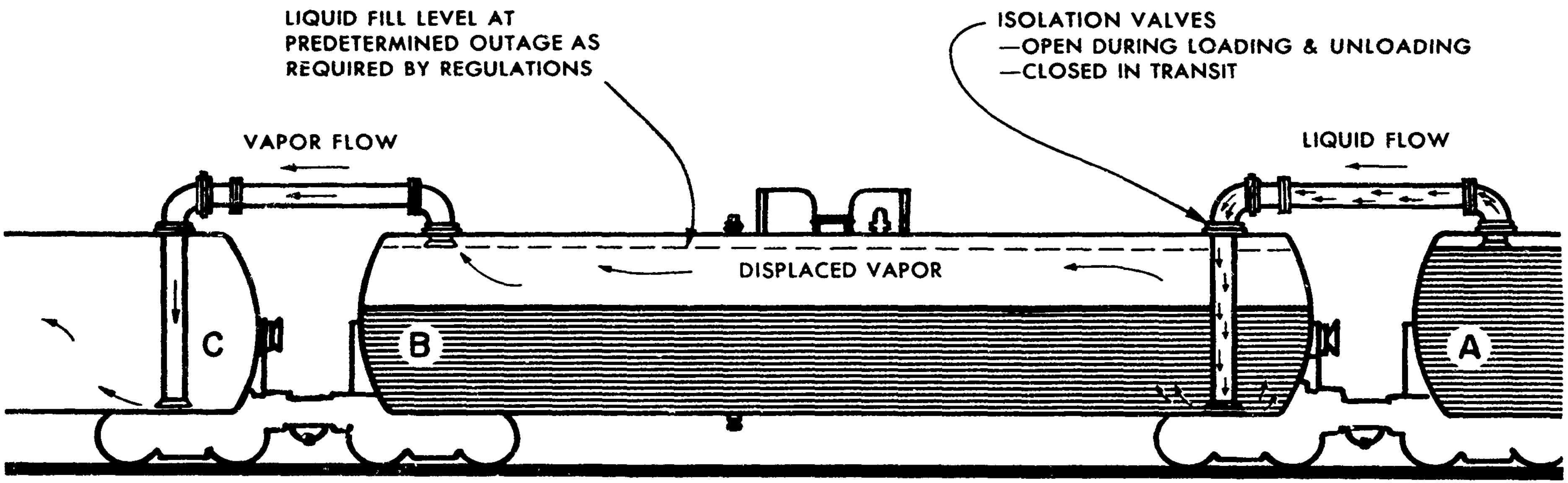


BASIC FLOW DIAGRAM DURING LOADING PHASE
INTERCONNECTED TANK CARS

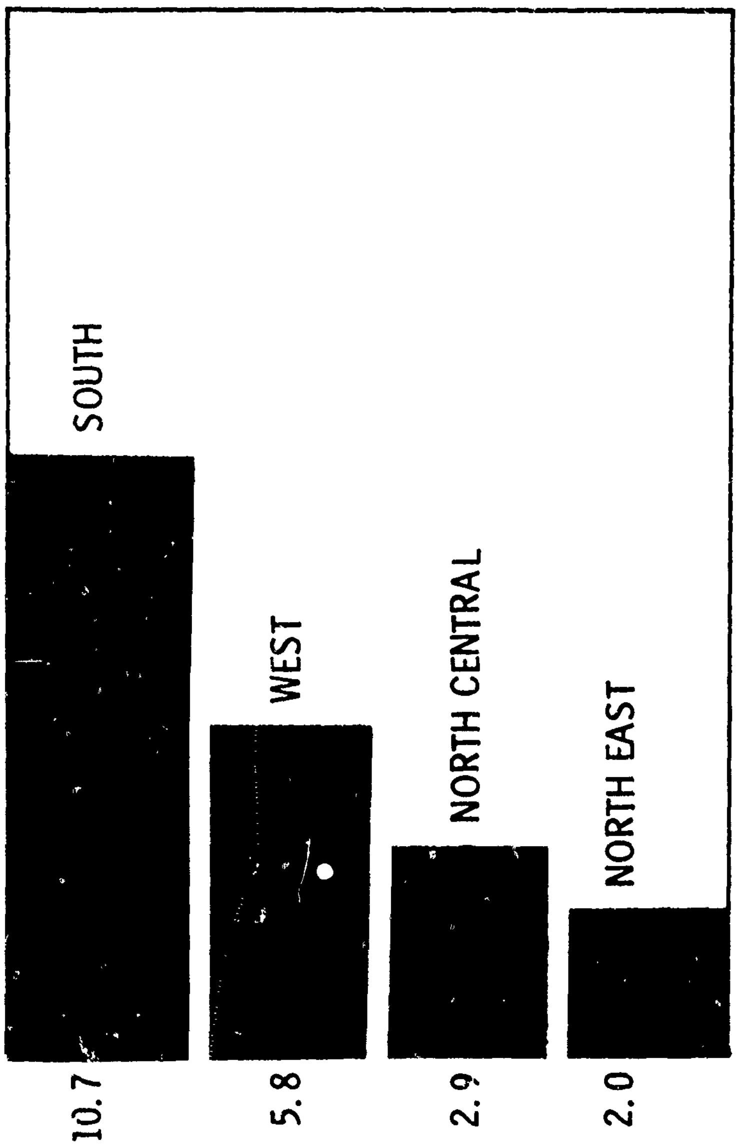
TRENDS IN MOTOR

- CONSOLIDATIONS / MERGERS
- SHIFT TO DIESEL FUEL
- STANDARDIZED WEIGHT / SIZE LIMITS
- CONSERVATION METHODS
  - OPERATIONS (MOTOR FOR MOTOR SUBSTITUTED SERVICE)
  - EQUIPMENT DESIGN
- INTENSE COMPETITION
- CONTRACT CARRIAGE
  - GUARANTEED RATES / VOLUMES
  - CUSTOMIZED SERVICE
- SAFETY STANDARDS
  - COMMERCIAL MOTOR VEHICLE SAFETY ACT S 1390
- LEVEL OF SERVICE
  - LONG HAUL VS. SHORT HAUL
- LARGER / LIGHTER EQUIPMENT

TRENDS IN RAIL

- RAIL MERGERS / TRACKAGE ABANDONMENTS
  - SERVICE IMPLICATIONS
  - COST FACTORS
- INCREASE IN RAIL TRAFFIC LONG HAUL VOLUMES
  - FUEL AVAILABILITY / COST
  - HIGH COST OF REBUILDING HIGHWAYS
  - POWER GENERATION (OIL TO COAL)
- UNIT TRAINS / RENT-A-TRAIN / PIGGYBACK
- NEW LARGER FREIGHT CARS
  - 90,000 NEW FREIGHT CARS IN 1979
  - 1,900 NEW / REBUILT LOCOMOTIVES
  - CAPITAL OUTLAY $13-16 BILLION BY 1985
- ENERGY CONSERVATION METHODS

1980-1990 PROJECTED POPULATION INCREASE



IMPACT ON SHIPPERS

- TRANSPORTATION MANAGEMENT
- MARKETING STRATEGY
- FINANCIAL PLANNING

DEPARTMENT OF TRANSPORTATION GOALS

- REGULATORY REFORM OF MOTOR AND RAIL
- RESTRUCTURE RAILWAY SYSTEM
- REVERSE TREND OF HIGHWAY DETERIORATION
- STREAMLINE INTERMODAL TRANSFERS

WHAT THE NATION'S TRANSPORTATION INDUSTRY NEEDS

- LONG RANGE STRATEGIC PLANS AND CAPITAL INVESTMENT PROGRAMS.
- SOUND, PURPOSEFUL CONSERVATION STRATEGY
- TEAMWORK AND COOPERATION AMONG DIVERSE INTEREST

GAO REPORT - "TRANSPORTATION ISSUES OF THE 1980S" - SEPTEMBER 8, 1980

AUDIT AREAS

- PLANNING/COORDINATING MULTI-MODAL/INTERMODAL TRANSPORTATION
- RESTRUCTURING/REHABILITATION OF RAIL FREIGHT TRANSPORTATION SYSTEMS
- MOTOR VEHICLE SAFETY
- DEVELOPING AND MAINTAINING HIGHWAY SYSTEMS
- IMPACT OF DEREGULATION
- DEVELOPING EFFICIENT AND EFFECTIVE MASS TRANSPORTATION SYSTEMS
- EVALUATING EFFECTIVENESS OF INTERCITY RAIL PASSENGER SERVICE
- DEVELOPING SAFE AND EFFICIENT AVIATION SYSTEM
- DEVELOPING MARITIME SYSTEM

GAO VIEWS OF GOVERNMENT RESPONSIBILITIES

- PROMOTE DEVELOPMENT OF EFFICIENT, ACCESSIBLE NATIONAL TRANSPORTATION SYSTEM
- ENCOURAGING FAIR COMPETITION AND PROTECTING THE PUBLIC FROM ABUSE OF MONOPOLY POWER
- PROTECTING THE SAFETY OF TRAVELERS AND CARGO
- BALANCING ENVIRONMENTAL, SOCIAL, AND ENERGY GOALS WITH TRANSPORTATION NEEDS

RECOMMENDATIONS TO SHIPPERS:

- DEVELOP STRATEGIES / CONTINGENCY PLANS
  - <u>SHORT TERM</u>
    - SERVICE DETERIORATION / RATE INCREASES
      - RESTRUCTURE CARRIER NETWORKS (ALLOCATION OF VOLUMES / MINIMIZE EMPTY MILEAGE)
      - NEGOTIATIONS (VOLUME INCENTIVES)
      - SHIFT SHIPPER SERVICES TO CARRIERS
      - REDUCE DELAYS
    - MANAGEMENT COMMUNICATION
    - SITE SELECTION (TERMINAL LOCATIONS)
    - SHIPMENT PLANNING / CONSOLIDATIONS
  - <u>LONG TERM</u>
    - MARKET / DISTRIBUTION
      - POOLING / INTERCORPORATE HAULING
      - PIGGYBACK
      - EXPLORE CONTRACTS
    - COMPUTER APPLICATIONS
      - RATE / ROUTE DATA BASE (ELECTRONIC DATA INTERCHANGE)
      - CARRIER PERFORMANCE
      - TONNAGE DISTRIBUTION
    - STAFF SELECTION AND TRAINING OF COMPETENT PROFESSIONALS

Remarks

Prepared for Delivery by

JOHN M. DONNELLY, JR.
Chairman of the Board,
The American Waterways Operators, Inc.,

at the Air Force Energy Awareness Week Symposium

San Antonio, TX
October 22, 1980

Good morning. I am John Donnelly, president of Ingram Barge Company of Nashville, TN. Ingram is one of the largest petroleum carriers on America's inland waterways, and the largest company engaged in waterborne transport of limestone.

I am also Chairman of the Board of The American Waterways Operators, Inc., the national trade association representing the interests of the barge and towing industry. Today, I will wear both my "hats" because each is relevant to the subjects at hand: transportation and fuel availability.

As head of a barge company, I am confronted daily with operational and policy questions dealing with fuel, now the single greatest direct cost in our industry. Our fleet of about 300 tank, deck and hopper barges is pushed by 19 towboats with horsepowers ranging from 2,400 to 9,000. Together, these boats total some 90,000 horsepower. When you consider that a working towboat each day uses about one hundred gallons of fuel for each one hundred horsepower, you begin to see the magnitude of our interest in fuel matters.

As Chairman of our industry's trade association, I am privileged to speak for our membership on issues of common concern. And, believe me, the cost, availability and efficient use of fuel are topics very much on the minds of all our members.

I am sure some of you have been wondering what place a representative of the barge industry has on the agenda of this Air Force-sponsored symposium. I think you will find that we share many concerns and, perhaps, even a common language. Let me give you a little background on the barge and towing industry.

We're in the business of moving bulk commodities on the 25,000 miles of navigable waterways in this country. Petroleum and petroleum products account for more than two-fifths of our traffic; coal represents another one-fifth; and the remainder consists mainly of grain, chemicals, and iron and steel. Throughout our areas of operation, we compete directly with other modes of surface freight transportation—particularly railroads and trucks.

About 12 percent of the nation's bulk cargo moves by barge; in 1978, this amounted to 662 million tons. We are able to stay competitive because barge transportation has certain inherent advantages--foremost among them being fuel efficiency.

Our studies show that the barge industry uses only about 270 BTUs per ton-mile, compared to 687 BTUs by rail, and over 2,300 BTUs by truck. Even when the question of route "circuity" is taken into account, barge transportation is substantially more efficient than all other surface modes, with the possible exception of large-diameter petroleum pipelines.

But don't get me wrong--it is not my intention to denigrate other transportation modes. Each has advantages that make it best-suited to meet particular shipping needs. For example, while barge transportation is cost effective and fuel efficient, its service area is limited by the geographical constraints of our river system. In addition, it cannot promise the delivery speed desired for many finished products or small items.

The point I want to make is that <u>all</u> modes of bulk freight transportation are fuel efficient, and each plays an important role in the nation's total transportation system. Working together, they move the products that fuel America's industries and utilities, and carry the fruits of this country's labors to domestic and foreign markets.

For these reasons, it is imperative that our freight transportation industries--barges, railroads and trucks, alike—receive the fuel supplies necessary to conduct normal operations. This is an issue that may not seem as pressing today as it did in the summer of 1979, for example, when fuel supplies were tight and the federal government started to get into the business of allocating this limited resource.

Subsequently, we witnessed the development of a so-called "fuel glut," which helped dissolve the memory of earlier shortages. I submit, however, that the world fuel situation is—and will continue to be—a very tenuous one. The current conflict between Iran and Iraq is a reminder that foreign fuel supplies are subject to forces well beyond our control.

Those of us in freight transportation business must anticipate the possibility of future fuel allocation periods, and work to assure adequate supplies to our industries. For our part, The American Waterways Operators, Inc., has been actively working with the Department of Energy and other federal agencies to reinforce our position on this issue.

Thus far, I have discussed fuel allocation and touted the outstanding fuel efficiency of the barge and towing industry. I would like to turn now to the topic of technological innovations in our industry. As it turns out, these subjects are closely related—most of the new technology under consideration today is aimed, directly or indirectly, at cutting fuel consumption.

Despite our relative advantage in fuel efficiency, the barge and towing industry is no less affected by soaring fuel costs than other businesses. We watched No. 2 diesel fuel prices jump from about 12 cents a gallon at the beginning of the 1970s to well over 80 cents a gallon by the end of the decade. Fuel costs now account for more than 35

percent of our operational costs. Consequently, we share the intense interest of other industries in finding new ways to reduce consumption.

Previously, the emphasis in new technology for the barge and towing industry was on increased power and cargo-lift capacity. Between the mid-1930s—when the first modern-type, twin-screw diesel towboats entered service—and the early-1970s, most technological improvements represented gradual refinements and improvements of equipment. There were few major "breakthroughs."

The introduction of the Kort nozzle, a steel shroud enclosing each propeller, greatly increased the thrust of towboats. It is now standard equipment. Hull designs have been improved, advancements in construction methods have increased hull stiffness and durability, cut weight, and helped reduce maintenance requirements. In addition, many of the small and medium-sized shipyards that serve our industry have instituted automated shipbuilding techniques that have improved efficiency and lowered costs.

The development of integrated tug/barge units—a system whereby an oceangoing tug pushes a barge with a notched stern—has improved towing operations in the coastwise and intercoastal trades. The introduction of deeper notches enables tugs to remain in the pushing mode in rougher weather rather than changing to the slower "pulling" mode with the tug using a towing line.

In addition, the development of more rigid locking methods for tug/barge units has improved rough water capabilities and lowered operating costs through smaller manning requirements. The tug/barge method, in general, has helped reduce construction costs and added to operational flexibility.

Undoubtedly the greatest change in recent years was the dramatic increase in towboat horsepower. The 1970s saw the introduction of the first 10,000-horsepower

towboats for use in line-haul operations on the Lower Mississippi. This power improved the ability of the boats to handle ever-larger barge tows, which now frequently number 35-40 barges heading downstream on that river, and even more barges upstream.

Between 1965 and 1977, the average horsepower of the towboat fleet increased by 95 percent. Because of operational limitations of the rivers, it is doubtful that horsepower will continue to grow.

Looking ahead, I see the following developments in areas aimed at improving fuel efficiency in our industry:

• First, we will see wider use of medium and slow-speed diesel engines capable of burning No. 6 oil, or a blend of No. 6 oil and diesel fuel. This technology has been available in Europe for several years, but has only recently been introduced in the United States through licensees, who will assemble the power plants in this country. No. 6 oil sells for about one-half the cost of diesel.

• Some of our industry members believe that the four-cycle engine will find greater prominence on our rivers. They believe it is more fuel efficient than the standard two-cycle towboat engine, and may also lend itself more readily to burning mixtures of heavier fuels. I should also note that the people who developed the two-cycle engine are working very hard today to make those engines more fuel efficient, also.

• Waste heat reclaimers will be used to furnish heat to living quarters on the towboats, rather than using a separate furnace.

• Bottom heat recycling systems will be looked at as a means of developing more thrust. One towboat builder, St. Louis Ship, already is

actively promoting the Rankin bottom-cycling system on its new towboats. This involves installation of a chamber, filled with special fluid, in the stack. This is heated by the exhaust and the resulting energy returned to the shaft.

- Some designers are reevaluating the use of controllable pitch propellers, a technique that was looked at in the past but generally set aside. The new economics of vessel operations has justified a "second look" at such ideas.

Other innovations will be tied to better information systems and the increased use of computerization in our industry. Consider the following items:

- One barge operator, National Marine Service Incorporated, has been involved in a cooperative effort with the Maritime Administration to develop a prototype Vessel Management Information System. It is designed primarily to track the financial and operational activities of a barge company, and provide information on such functions as scheduling and ratemaking. Typical data to be available through this on-line system include boat and barge position, tow make-up, customer information and vessel movement histories.

- Automated engine rooms are already in use today, but they will become even more sophisticated, with computer banks monitoring such items as horsepower and fuel consumption.

- Also monitored will be towboat vibration levels. Engines, gears and shafts will be analyzed with the aim of producing smoother operation and reduced noise levels.

• Communications systems have improved greatly in recent years, but will play an even greater role in vessel operations. For example, WATERCOM, a vastly improved communications system for barge operations on the Mississippi and Ohio Rivers and their tributaries, hopes to begin operations in the next year and a half. Companies who join the WATERCOM system will find communications between towboats, locks and home offices as easy as picking up a telephone, and as rapid as land-based communications systems.

The WATERCOM system will involve not only voice communications, but also information, including data from sensing devices aboard the towboat. This data would be fed into land-based computers for monitoring and analysis.

I should also note that aids-to-navigation will be further improved to provide more information on the speed and direction of other vessels, and distances to stationary objects. Bridges will be equipped with radar transponders on piers, and centerline indicators for better line-up of barge tows for safe passage in inclement weather. Forward and side-scanning fathometers will indicate the depth of water ahead and to the sides of the towboat. These developments are not related directly to fuel efficiency, but they will help the barge and towing industry maintain the excellent safety record it enjoys.

In order to take full advantage of the technological improvements I have just discussed, it is imperative that our waterways system be modernized. I am referring not so much to the rivers themselves, but instead to the man-made facilities along them, most of which were developed in another era of transportation requirements.

When the Ohio River project was completed in the 1920s, for example, the U.S. Army Corps of Engineers projected 13 million tons of traffic annually. The Ohio handled 23 million tons its first year, 152 million tons in 1978, and is expected to handle 200 million tons in 1980. The Ohio locks and dams are approaching 60 years of age.

The Gulf Intracoastal Waterway, which is celebrating its 75th anniversary this year, was expected to handle 5 million tons annually. In 1978, it carried 120 million tons.

Backups of 60 barge tows are routine at Locks and Dam 26 on the Mississippi River just below its confluence with the Illinois. It frequently takes 2 1/2 to 3 days for a tow to clear this bottleneck. The Corps has gotten the green light to go ahead with a replacement lock there--following funding delays and court battles with the railroads and environmental groups--but it is expected to be another 8 to 10 years before the new, larger facility is completed. By that time, demand will already meet the enlarged capacity.

There are several more examples, but the point is that many of the facilities are aging, deteriorating and inadequate. The problem will be further exacerbated by a projected doubling of inland waterways tonnage between the years 1976 and 2000.

Another constraint to barge operations is the inability of the Corps of Engineers to maintain authorized dredging depths on several segments of our waterways. This problem arises not through any fault of the Corps, but through the excessive regulatory and legislative dredging restrictions placed on that organization. Today, the Corps must consult with regional offices of such federal agencies as the Environmental Protection Agency, the Fish and Wildlife Service, and the Soil Conservation Service, not to mention a myriad of state agencies.

This summer there were numerous reports of grain barges running aground on the Mississippi, Arkansas and Missouri Rivers because of inadequate channel dredging.

We realize, of course, that river capacity, by its very nature, is finite. There may eventually come a day when commercial traffic reaches the limits of actual river size. The barge and towing industry asks only that inadequate man-made facilities and maintenance efforts do not, in themselves, stifle our efforts.

Our industry plays a vital role in the nation's transportation system, and it will be called upon in the future to handle even more of this country's shipping requirements. The projected surge in U.S. coal exports is but one of the challenges ahead.

A primary effort of our trade association is to ensure that the nation's legislators and regulators recognize the necessity of eliminating unnecessary constraints on the inland waterways.

From an operational standpoint, the barge industry has been doing its part to be a "good citizen." We have kept pace with the growing demands of America's shippers. We offer low-cost, fuel-efficent, and safe transportation. And we are actively seeking technological improvements to help us continue our solid record of performance.

Our message to America's transportation policymakers is simple: Let us do our job, and you can be sure we'll do it well.

Thank you.

# # #

CONTROL OF TRANSPORTATION EQUIPMENT IN
NATIONAL EMERGENCIES

PRESENTED BY

LEONARD P. MANDRGOC
DEPARTMENT OF TRANSPORTATION

PRESENTED TO THE
INDUSTRY-MILITARY ENERGY SYMPOSIUM
21-23 OCTOBER 1980
SAN ANTONIO, TEXAS

CONTROL OF TRANSPORTATION EQUIPMENT IN NATIONAL EMERGENCIES

I'm with the Office of Emergency Transportation (OET) in Washington DC, and our primary function is to plan for emergencies. I want to tell you a little bit about the background of OET, what we do in the Department, and what our functions are, and just briefly go through several incidents to give you some idea of what we're involved in. Hopefully this will tie in with all the other transportation and fuel discussions.

This is public law 89-67, which established the department and the only thing I want to point out here is that the Secretary is charged as stated: "The secretary shall exercise leadership," which includes both national defense and national and regional emergency.

Now, we're not alone in this program. So I'd like to step off for a minute and show you another slide that might put this in a little better perspective. The President is up top naturally and the Federal Emergency Management Agency is a new organization that's just been established. It's a grouping of three organizations—the former Federal Disaster Assistance Administration, Defense Civil Preparedness Agency and the Federal Preparedness Agency. These organizations were together sometime back under the old Office of Emergency Preparedness, but a few years ago it was broken into three separate organizations. So instead of getting policy guidance for emergency planning from one place, we got it from three, and that made it very difficult. Finally they put it back together and they called it FEMA, Federal Emergency Management Agency. They are in essence the President's emergency coordinators. They set up plans and programs for all of government.

Their predecessor agencies did the same thing, and they set up what we call a National Plan. This is just a picture of the cover. It was prepared in the 60's, but it's still valid. This plan sets forth broad responsibilities and relationships within the Department, provides guidance for state and local governments in planning, and most importantly it sets up a single function manager for major economic sectors. In other words, in case of emergency, the Secretary of Agriculture is in charge of all agriculture, the Secretary of Transportation for all transportation, the Secretary of Labor for all labor relations. These things are very important, as you'll see as we go on.

Based on this national plan and other laws they came up with something I think most everybody is aware of, executive order 11490. Now these few words summarize the Secretary's responsibilities. It covers all modes of civil transportation.

This same order assigned operational preparedness responsibilities to the Civil Aeronautics Board, to Interstate Commerce Commission and to the Maritime Administration to do their emergency planning under the coordinating authority of the Secretary of Transportation. They have no responsibility to us, but yet they are to do their planning under our authority. This creates many many problems.

Now both the original law and this law provide for the Secretary to have the leadership, and that's what I want to get across, not only in defensive emergencies but also in nondefensive emergencies. Now how do we get this job done. This little block in the center is our office. It has only a few people in it but it looks like it is the center of the universe. But we have a lot of responsibility. We are the emergency coordinator for the Secretary of Transportation. In each of the Assistant Secretary offices (above) we have one person who is responsible to us for planning and preparedness planning. On the lower level you see the Coast Guard, the FAA, the Federal Highway Administration, the Federal Railroad Administration, the National Highway Traffic Safety Administration, Urban Mass Transit, and St Lawrence Seaway. These organizations each have an emergency coordinator in their office. The Coast Guard has a much bigger emergency organization than we have. So does the Federal Aviation Administration and the Federal Highway Administration, but they have a responsibility to coordinate with our office as do all the other modes of transportation. In addition, we coordinate from our office with the Federal Emergency Management Agency that I showed you earlier and also with the Interstate Commerce Commission, the Civil Aeronautics Board, the Maritime Administration, and the Corps of Engineers. So you see, there is a lot that happens right through our little office.

And in addition to this, we have a field organization that I think would be most appropriate to show you at this time. This is the regular ten standard regions. In each region we have what we call a Regional Emergency Transportation Coordinator (RETCO). He is usually an administrative head in one of those regions. For example, in regions one and two we have a Coast Guard Admiral in charge. Region nine and region ten have other Coast Guard Admirals who are the coordinators for the states in their regions. In regions three, five, seven and eight across the heart of the country, we have the Federal Highway Administrator, in each of those regions, as the emergency coordinator. In regions four and six and up in Alaska, we have the Federal Aviation Administration. In case of emergency, of any kind, defensive or nondefensive, we turn to him to run the operation within the region. This region (region six) includes the states of New Mexico, Oklahoma, Texas, Arkansas and Louisiana. All other departmental operating elements—the Urban Mass Transit, the Coast Guard, etc. in region six are responsible to the RETCO in Dallas. This is our concept of decentralizing it; getting it away from Washington because we can't do it with our small operation. We have to depend upon a regional breakdown to get the job done.

So much for directives and laws and organizations. Now I'd like to show you how our crisis level situations would work and how we do into different levels of operations. Now we have what we call level one, and these levels are just for discussion purposes. Level one is just above normal activity. You might have a little cold weather crisis like we had in 1977, a selective rail strike, or Skylab reentry. Something like that, we would get involved in but we really wouldn't activate too many more people beyond our OET operation. We did activate, incidentally, region six during Skylab reentry because there was some possibility that it might land in your area but luckily the people in Australia picked it up for us. In the second level, we have a clear national impact. That would be a general strike of a mode. For example, if the Southern Railroad went on strike, it would have tremendous impact on a major portion of the United States. In this situation, we would get deeply involved and would involve more people. The Secretary, at level two, could ask for priorities and allocations authority from the President, to allocate transportation and control the use of equipment. Now, level three is a situation in which there is a formally declared emergency. This is when priorities and allocations would automatically come to us and the whole Federal level would intensify. The fourth case is the worst case situation, a nuclear exchange. Plan D would go into effect. It provides what is necessary to get the job done. It provides the Secretary with expanded authority. He gets executive management of the transportation system; the direction and control of the nation's total civil transportation resource. He is now running the transportation systems.

As I said, we cannot run the transportation system in the Department of Transportation because we don't have operators to handle the barge system, the railroad system, the highway system. So what we have is a standby organization, the DOT emergency organization. Now, this is made up of fifty percent federal employees and fifty percent transportation executives. Within the Department we have about 400-425 transportation executives from throughout the country who have volunteered to come to work for the government, for the department, in case of national emergency or major disaster, to assist the Department and the country in running the transportation system. These people run the transportation system now. They come from the railroads, from the highways, from the barge company and from the maritime industry. We don't just go out and find these people, they are selected because of their willingness to participate. This is a very dedicated group. We have a training session every year in all ten regions. These people come to these meetings at their own expense. They train for two days. We provide them with information throughout the year and we intend to expand the training operation to include a longer training program because they demand it.

Now lest I leave you with the thought that the worse enemy might not be the enemy itself but the feds trying to run the transportation systems, I'd like to show you some of the principles that we intend to operate under. The degree of control would be based on the additional

authority granted. We don't want to go beyond the authority. Let's just do what we have to do and get out of the way. The second thing is to do the job through the existing transportation operating agency. Don't establish a new organization. Use the FAA people. Use the Federal Highway people. Use the Coast Guard people, the National Highway Traffic people. Use the ICC, the Maritime Administration, the Corps of Engineers. Don't establish anything new, just use what you have to get the job done and apply it to the degree necessary. Just get it and get out. Retain it only as long as you have to have it. If the system is operating, get out and don't bother it. That's our concept. Don't get involved if the transportation system is running and is efficient. Maintain the normal shipper carrier relation through to the highest degree possible. Do it the way you have been, when you have a problem, then you come and seek advice from your regional people or from your national people. Let's keep it that way. Naturally management concepts will vary according to the mode. There may be some differences. We may have to have more controls in the maritime then we will have on the railroads, or vice versa depending on the situation.

This is a very brief discussion of what we do but I'd like to take a minute or two to talk about nondefensive emergencies. We have a crisis action plan that we established some years back to handle nondefense emergencies. Let me give you some examples. At Three Mile Island (TMI) I had the fortune or misfortune of going to Three Mile Island during the disaster. We got involved when they were moving contaminated water from Three Mile Island to South Carolina. A second incident in this TMI thing concerned specialized railroad cars. They had so much contaminated water they didn't know what to do with, they wanted to put it in some kind of storage cars until they got clearance to move it. So we contacted the ICC and they contacted the American Association of Railroads. Both responded rapidly. We found there were 104 cars in the United States, but they belonged to private companies. So the ICC had to go in and do the negotiations and get some of these cars moved to Three Mile Island so that the water could be drained out of the reactors.

We have been involved in the Mount St Helens disaster with the ashes spewing all over the states of Washington and Montana. They had engine problems—they were sucking in this ash and it would freeze the engine and the car would stall. Within twenty-four hours General Motors, Chrysler, and Ford had a task force set up in Detroit to look at the engine problem. We had the Tanks Command in Dearborn, Michigan involved because of their research with filters.

We got involved in the 1979 fuel crisis when we had a shortage of diesel fuel at the same time you had the independent truckers' strike. In the state of Montana, there was no diesel fuel. The truckers were calling us and they are talking to us rather gingerly and they asked us to get some fuel out there. We had a crisis center operating,with representatives from DOE, Justice, ICC and Agriculture, the DOE who went out to Montana and explained to them how they could get the fuel moved from the state set aside into the local stations so the trucks could move.

So we do get somethings done. Generally, this is what we're about. As I say, if you see us anywhere you know there is trouble, and I hope that you never see us. We hope this has been of some value. Thank you very much.

ENERGY SYMPOSIUM

Under the auspices of
The Department of the Air Force
Kelly A.F.B.

El Tropicano Hotel, San Antonio, Tx.
Oct. 21-23, 1980

Paper by C. Harry Smith
Air Logistics Corporation
entitled

"Air Transportable Fuel Systems"

This is a reading transcript, with corresponding illustrations, of the paper to be presented at the Symposium.

AIR LOGISTICS CORPORATION
3600 EAST FOOTHILL BOULEVARD PASADENA CALIFORNIA

AIR TRANSPORTABLE FUEL SYSTEMS

My responsibility is to describe and illustrate the Air Transportable Fuel Systems produced by Air Logistics Corporation for Military operations. I would like to say at the outset that the fact that Air Logistics Corporation is participating here at the Air Logistics Center is merely a coincidence of name, and in no way implies that the Air Force is dabbling in capitalist enterprise on the side! I must assure you that we are linked by common enthusiasms only.

We have taken the liberty of subtitling our presentation "Total Fuel Logistics", because we like to think that ongoing analysis of the changing needs of the Military not only leads to the most effective equipment for each particular purpose, but also helps us to identify the complete spectrum of requirements existing at any one time. Now, I know that it's more than likely that at the end of this talk someone can legitimately say "Ah! But have you thought of this situation?", or "How do you propose handling these circumstances?". All I can say is that such questions are more than welcome because they do help us to fulfil our objective of providing for every conceivable need. In other words, as we've all heard with great frequency recently, "I'm glad you asked me that!"

First, I would like to define more exactly what we mean by "total fuel logistics". AIR LOGISTICS CORPORATION DEFINES TOTAL FUEL LOGISTICS AS THE ABILITY TO PROVIDE PRIME WEAPONS SYSTEMS AND THEIR SUPPORT EQUIPMENT WITH CLEAN, DRY, STERILE FUEL IN THE PROPER QUANTITIES, FLOW RATES AND PRESSURES - ANY TIME, ANY PLACE. Clean fuel in the proper quantities, flow rates and pressures is achieved by precise engineering, with the appropriate range of adjustment for varying requirements, and the requisite overall safety provisions. "ANY TIME, ANY PLACE" IMPLIES SPEED - AND - MOBILITY. Therefore - all - our - systems - are - airborne - or - air transportable - and - rapidly - deployable.

The systems fall into three distinct categories, which collectively endow military forces with highly effective fuel management, and enhanced capabilities and logistics. The categories are:

Airborne fuel storage and dispensing systems which provide refueling capability at remote locations for aircraft, helicopters and armor.

Quick conversion kits for existing cargo and passenger aircraft, for transporting large quantities of bulk fuel.

Air transportable, ground fuel storage and dispensing systems utilizing redeployable collapsible tanks.

Figure 1, the fold-out schematic diagram, is intended to cover examples of military operations, from bulk storage through various field operations out to what might be called Special Operations.

Symbols in the schematic are reference lettered to the legend. The diagram is divided laterally into three parts. The top part represents air operations. The middle part represents fueling ground vehicles using air supply, and the lower part is devoted to the supply of potable water. There are four sections separated vertically, which we have called Fixed Base, Forward Area, Combat Zone and Special Operations, which may be long range specific missions by small task forces. The dotted lines show the tracks of airborne supply vehicles. The hard lines generally represent fueling hoses. The larger rectangles lettered B denote ground storage tanks. The small symbols are pump sets or refueling modules. With one exception, all these units have wheels for towing.

Starting in the air operations section, fuel is drawn from bulk storage and pumped by a 600 gpm pumper A by pipeline to ground storage at B. The pipeline can of course be virtually any length, with intermittent pumpers to boost the pressure. Fuel is drawn from ground storage by the 300 gpm modules C, filtered, and delivered through pairs of hoses with single point nozzles. The nozzles incorporate surge suppressors. The modules are driven by internal combustion engines, with flow controls which automatically cut back the engine to idle at the completion of refueling. Multi-fuel engines are optional.

Next is a similar operation for helicopters. In this case the Chinook is fueled at both sides simultaneously through single point or gravity nozzles as required.

Next, we come to bulk fuel delivery from storage to the forward area. The fixed wing tanker is fitted with a quick conversion kit of tankage and pump sets. It is loaded with bulk fuel from the pipeline or ground storage and delivers into ground storage in the Forward Area. If preferred, the tanker can load itself with its own pumps.

The tanker can also be configured for Alternative Capability Equipment. This comprises the addition of a filtration module, with hoses, nozzles and surge suppressors which permits fueling directly into aircraft. A tactical situation calling for this equipment might be where a tanker could put down on any suitable paved surface used by combat aircraft such as the AV-8 shown at E.

Still in the Forward Area, systems are shown for fueling medium and heavy lift helicopters. Bulk fuel in ground storage is pumped to the local site, or drawn directly from storage, and filtered and dispensed by 100 gpm modules F. Each module has an accompanying hose storage cart which can be towed in tandem with the module.

For operations in the Combat Zone, up to 2000 gallons of bulk fuel can be picked up from storage in the Forward Area, carried by sling tank and set down at pre-determined sites to "hot fuel" fixed and rotary wing aircraft.

The fueling module H is a self-contained unit giving 50 gallons per minute and is arranged for air transportation by snapping it on to one skid of a Huey.

The helicopter tanker E, or flying service station - sometimes irreverently called the Flying Cow -, carries cargo fuel and pumping equipment. Fuel is picked up in rear areas and dispensed in filtered condition at distant points to marine vessels such as hovercraft or patrol boats, and to fixed and rotary wing.

Moving now to the center section of Figure 1, similar systems apply to ground vehicle fueling, but at lower rates of flow.

Bulk fuel is pumped into storage at B and filtered and dispensed to armor by 100 gallon per minute modules with twin hoses. A similar system, BH, with a 50 gallon per minute module, fuels general service vehicles. The helicopter tanker E replenishes ground storage in the Forward Area and the sling tank delivery G provides a choice of site.

For fueling armor or other ground vehicles in the Forward Area, the system is much the same as in Fixed Base operations, except that ground storage is replenished by helicopters carrying bulk fuel by internal or sling tanks. These systems are illustrated at BF and GH.

At K, a tanker APC is configured in much the same way as the helicopter tanker, for fueling armor in the Forward Area. In the Combat Zone, the helicopter tanker can refuel armor directly, or replenish laid down storage for refueling APC's (L). The last illustration in the center section shows the helicopter tanker refueling ground vehicles by the same system as that in the illustration above.

The lower section of the schematic deals with potable water distribution.

We included potable water as an essential logistics commodity because sometimes it ends up as the poor relation of fuel. It can be transported in a similar manner to fuel, provided of course that the tanks are very clearly marked and segregated. A purification plant M puts water into bulk storage, a pump set N provides loading capacity and fixed or rotary wing aircraft deliver it to Forward Areas.

In the Forward Area, water arrives from bulk storage and is transferred to ground storage P from which it can be pumped at Q into water tankers or dropped at advance points by sling tank R for dispensing into ground service vehicles or portable containers.

Since we rely heavily on airborne and ground pillow type tanks, I'd like to outline our philosophy in their use.

These do not resemble the popular concept of bladder tanks. They are of extremely rugged construction, with molded-in tiedown and restraint harness which preserves their integrity under flight loads up to 8 G. A unique internal baffling system limits in-flight sloshing to less than 1 cycle.

All airborne tanks are designed to fit standardized pallets, facilitating installation and eliminating problems of footprint pressures.

Building systems around collapsible tanks does of course maximize their prime advantage in the ability to employ them in quick conversion kits, to deploy them rapidly to selected sites, and to move them from one site to another. It isn't vital to air transport them - they can be moved by truck, and it's possible to use them to convert a truck into a temporary fuel or water tanker.

Dispersal of fuel supplies in a larger number of tanks drastically reduces vulnerability.

Once again, the air tanker or helicopter sling lift can place fuel when, and where it is needed. Collapsible tanks, preplaced for future use, present a low profile and can be camouflaged easily with local materials.

Lastly, and in our view most important, collapsible tanks leave no explosive vapor space above the fuel when only partially full.

The next series of illustrations shows some of the systems in the schematic.

The first two are fuel - or water - tanker quick conversion kits for cargo and passenger aircraft.

Figure 2. This shows the installation in the French C-160 Transall, carrying bulk fuel in a 3000 gallon tank with a 600 gpm pumping set.

Figure 3. This is the C-141 installation - 9000 gallons in 3 tanks, with an onboard pumping capacity of 1200 gallons per minute.

The next two figures show airborne servicing systems for fighter and gunship refueling.

Figure 4. Here the C-130 is provided with alternative capability equipment. The basic system comprises 6000 gallons in 2 tanks, with pumping modules delivering 600 gpm. Loading takes 10 minutes and offloading 5 minutes. The addition of a filtration module permits dispensing directly into aircraft. The filtered system delivers 300 gallons per minute with surge control.

I should point out here that with all these systems the aircraft can be converted from normal transports to tankers in 30 minutes.

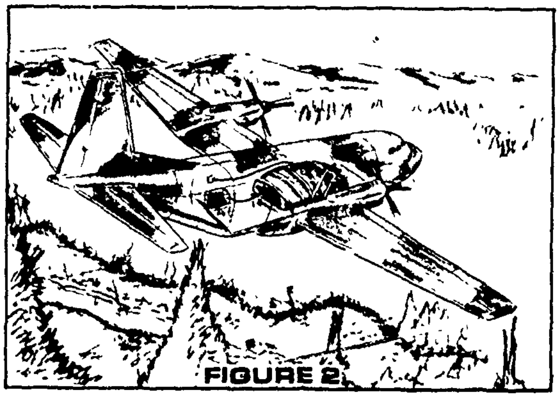


FIGURE 2

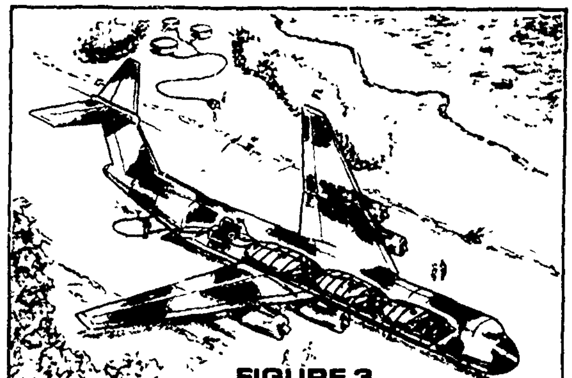


FIGURE 3

FUEL (OR WATER) TANKER - QUICK CONVERSION KITS FOR CARGO AND PASSENGER AIRCRAFT AND HELICOPTERS

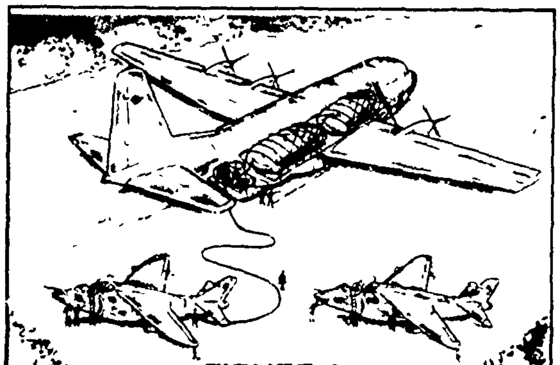


FIGURE 4

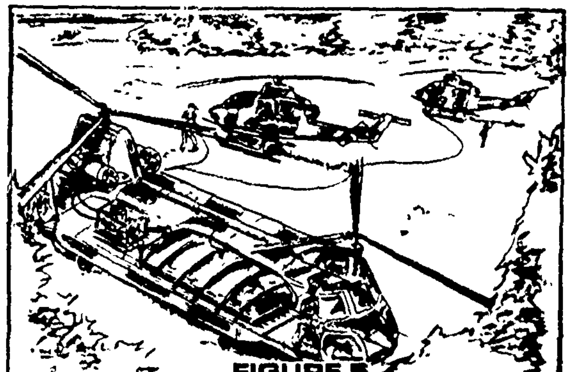


FIGURE 5

AIRBORNE FUEL SERVICING SYSTEMS FOR FIGHTER AND GUNSHIP REFUELING IN FORWARD AREAS

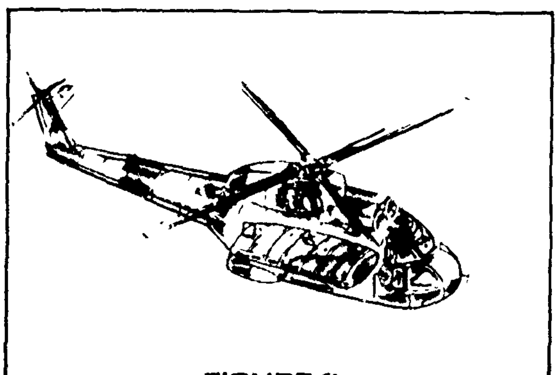


FIGURE 6

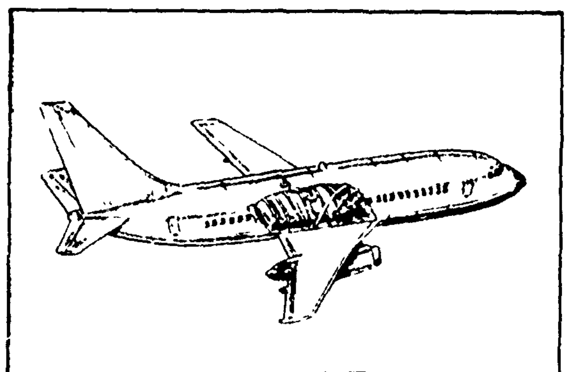


FIGURE 7

AIRCRAFT AND HELICOPTER RANGE EXTENSION KITS

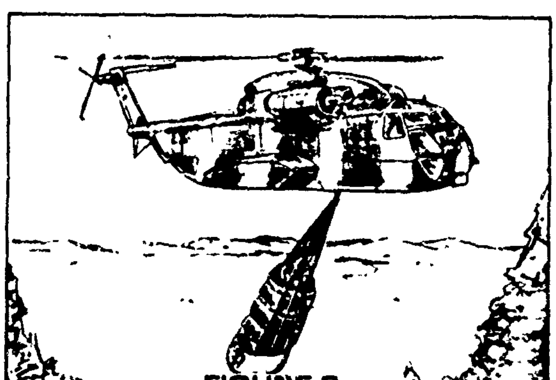


FIGURE 8

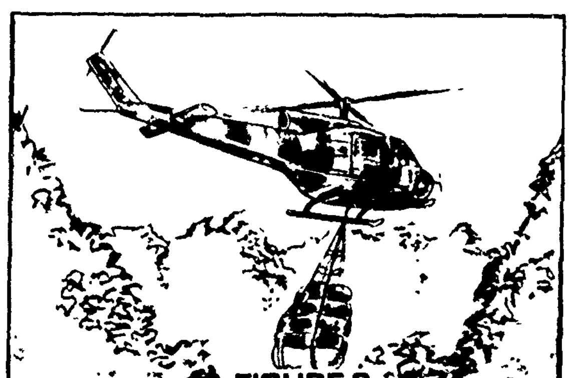


FIGURE 9

COLLAPSIBLE EXTERNAL TANKS FOR FUEL (OR WATER) DELIVERY

Figure 5 shows the installation in the Chinook. 2000 gallons with a 100 gpm pumping set, which can refuel airborne or ground vehicles anywhere a Chinook can set down.

The next pair of illustrations show range extension kits.

Figure 6. Because of the ease with which they can be installed, collapsible tanks offer a simple method of extending range. These tanks are provided with submerged pumps for feeding into the aircraft system. This illustration shows a 600 gallon tank in a French Puma. The Army recently used a similar system to deploy a flight of 4 Chinooks from Colorado to Germany in operation "Northern Leap".

Figure 7. Ferry range extension is also used on delivery flights overseas of medium range commercial aircraft such as the Boeing 737 and Douglas DC-9. Col. Rockwell used a 4000 gallon range extension system like this in his North-South Polar flight with a Boeing 707. The implication here is that in wartime emergency, commercial aircraft can be quickly converted to bulk fuel tankers or, for that matter, clean fuel dispensers for direct servicing. The tanks and pallet sections are introduced through the passenger door and tied down to the existing seat rails. Some of these installations do not use pumps, but transfer the fuel to the airplane system by cabin air pressure. The last pair in this group show helicopter sling tanks.

Figure 8. This is the CH-53 carrying 2000 gallons. Sling tanks are laid - not dropped - on the ground, and have a scuff panel at the base to eliminate abrasion.

Figure 9 shows the Huey transporting 500 gallons as an external sling load.

The previous illustrations have concentrated upon the transportation of fuel as bulk supply, as ready-to-use fuel for direct servicing from the tanker, and as quickly - installed kits for range extension. We come now to refueling installations capable of rapid relocation where the situation so dictates.

Figure 10 shows a typical setup for tactical operations. Fuel is delivered by pipeline, tank truck or air tanker and pumped into ground storage. Mobile 300 gallon per minute hydrant systems are located in the shelters. Fire protection systems, integral with the pumping modules, are deployed to the refueling area and dispense light water foam over a radius of 250 feet with a minimum endurance of 5 minutes. The complete fueling system can be flown into a site and set up in a short time. For removal of operations to an alternative site, tanks like these would probably be pre-positioned.

Figure 11 illustrates a dispersed hardened shelter installation employing below-ground fuel storage and pumping equipment. Fuel is replenished through a surface connection. The pumping and filtration module is self-contained and driven by an internal

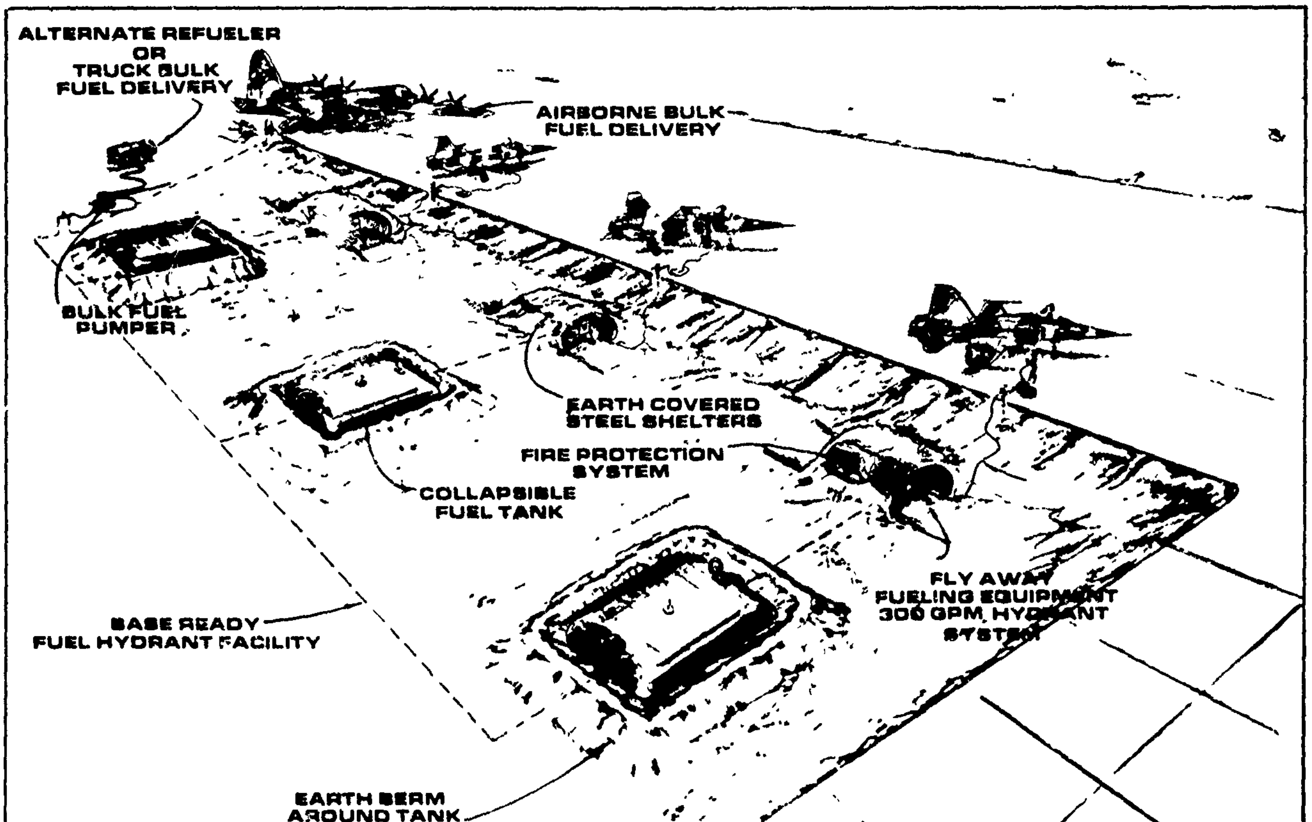


FIGURE 10

AIR RELOCATABLE HYDRANT FACILITIES FOR FORWARD OR ALTERNATIVE BASES

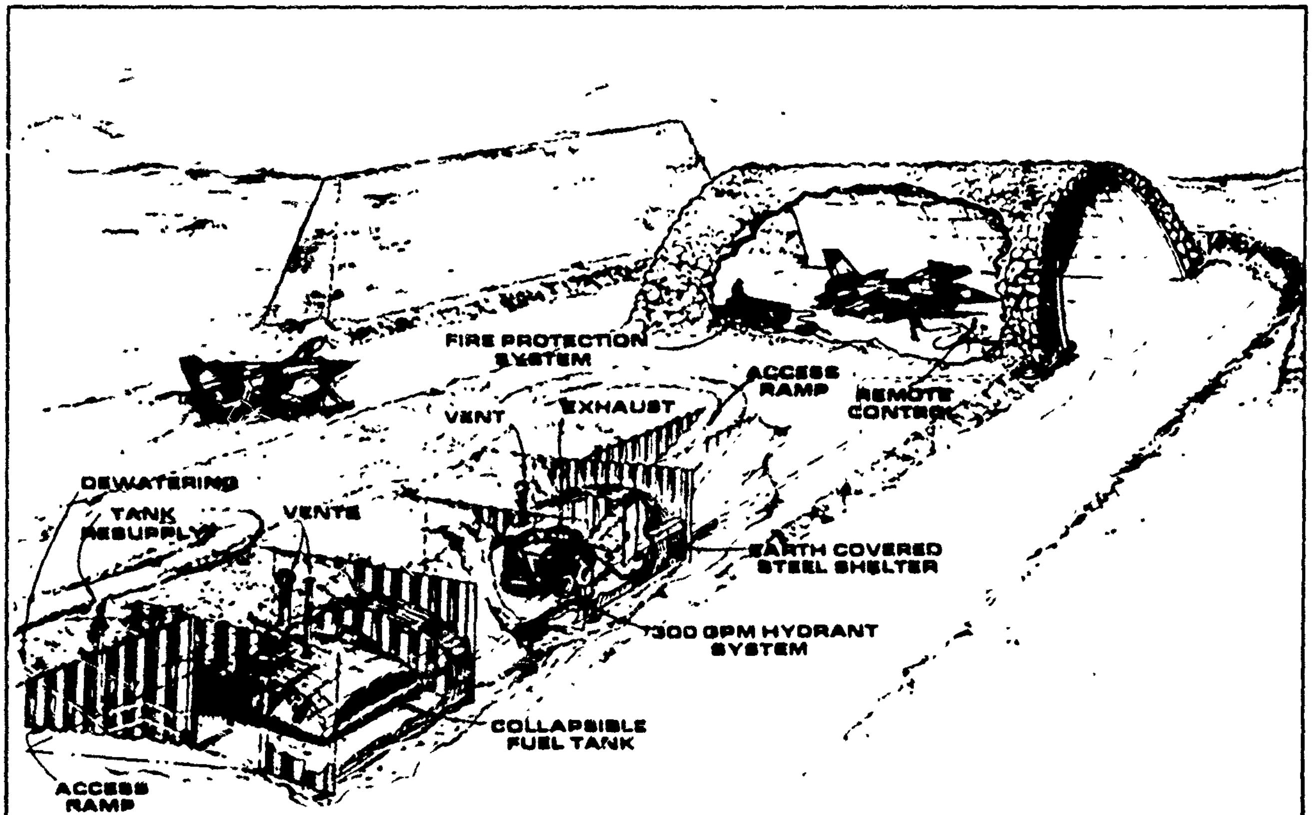


FIGURE 11

AIR TRANSPORTABLE HYDRANT SYSTEMS FOR DISPERSED HARDENED SHELTER FUELING

combustion engine. The delivery line is underground, and the only fueling equipment above ground is the hose in the shelter with its remote controls. While this is, in essence, a more permanent installation, the complete set of equipment can of course be quickly air transported to alternative prepared sites.

Figure 12 introduces a short series of illustrations of field operations. Here the helicopters are "hot fueled" in the Combat Zone.

Figure 13 shows the CH-47 carrying a complete system to a refueling point. Extra tanks and pumping module in the helicopter, with fuel carried by sling tank.

Figure 14 depicts fueling armor. The system is similar to that in the helicopter and is installed in an armored personnel carrier.

Figure 15. The Huey carries 500 gallons externally for small numbers of vehicles needing only modest quantities of fuel.

Figure 16. Where practicable, the flying service station, with fuel and pumping and filtration equipment, can fuel ground vehicles directly by landing alongside.

Figure 17 shows the same system servicing coastal and riverine craft.

Figure 18. For laying pipelines, the helicopter carries the pipe sections and couplings, and the 600 gallon per minute booster pump - or pumps, depending on the length of the line.

Figure 19. This shows the small end of the range of flow, the 50 gallon per minute fueling set with filtration equipment, snapped on to the helicopter skid for delivery to remote areas and setting up on the ground.

I might perhaps anticipate a question here by saying that, within their general categories of tank capacity and pumping flow rate, the systems have interchangeable and standardized connections. This facilitates pumping between tanks, for instance in replenishing a regular ground storage tank from sling tanks, or filling an empty sling tank to meet an emergency elsewhere.

Figures 20 and 21 show representative examples of the hardware we have been discussing.

Lastly, Figure 22 shows selected field operations.

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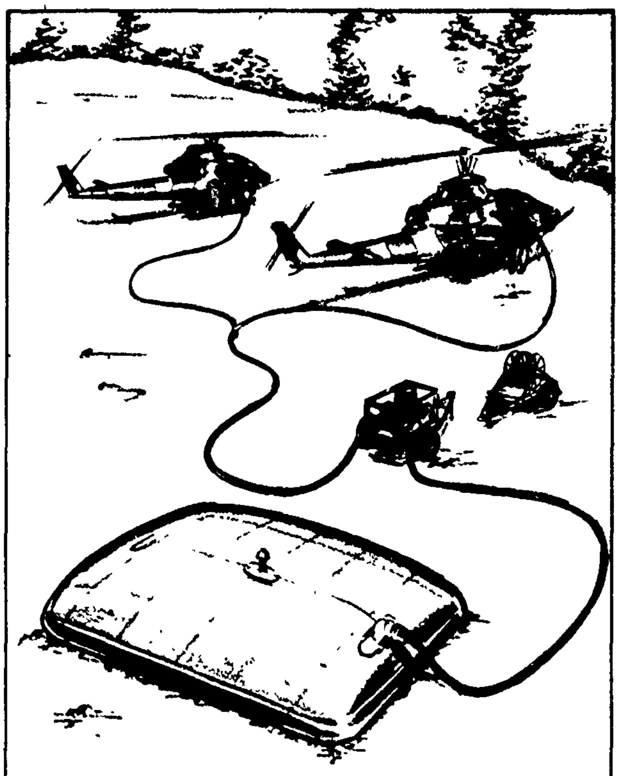


FIGURE 12

"HOT" FUELING (ROTORS TURNING) IN THE COMBAT ZONE

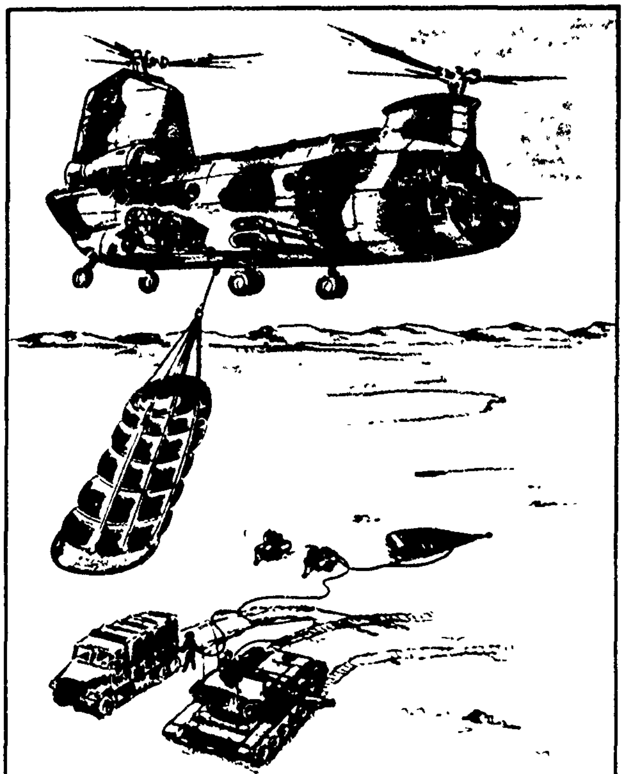


FIGURE 13

AIR TRANSPORTABLE FORWARD AREA FUELING SYSTEM

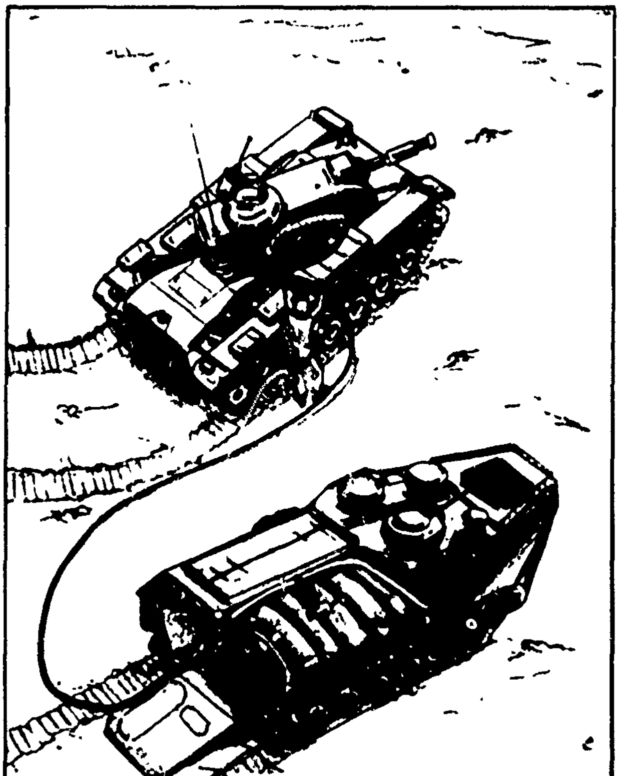


FIGURE 14

ARMORED FUEL SERVICING SYSTEM

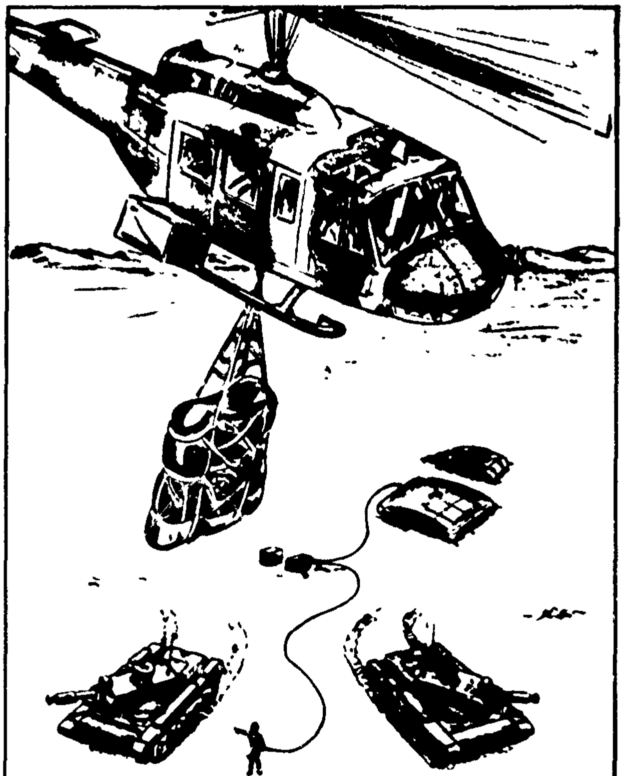


FIGURE 15

REMOTE AREA ARMOR FUELING

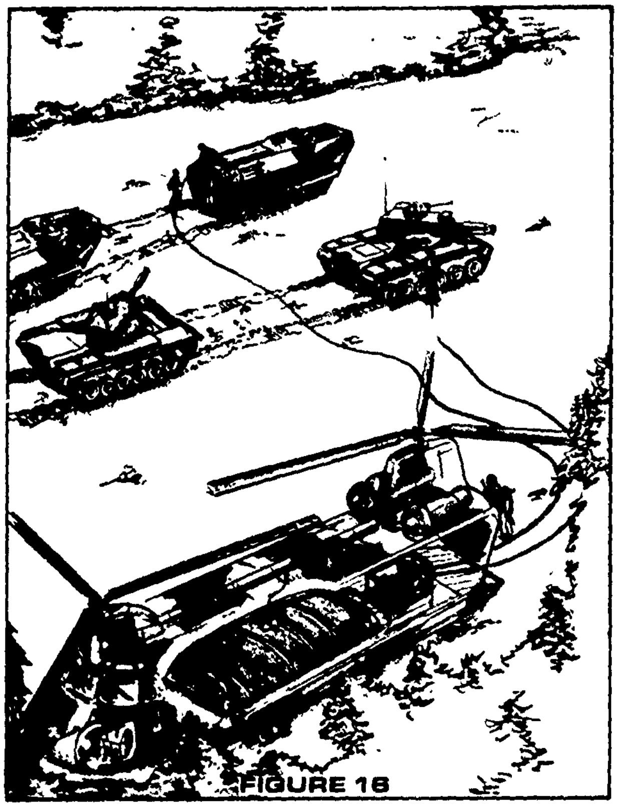


FIGURE 16

ARMOR FUELING FROM AIRBORNE FUEL SERVICING SYSTEM

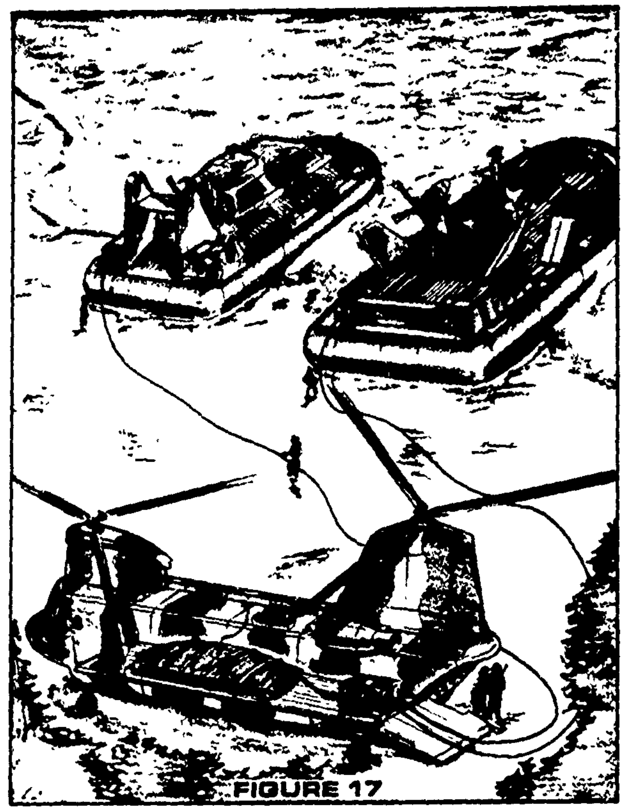


FIGURE 17

AIRBORNE FUEL SERVICING SYSTEM FOR MARINE VESSELS

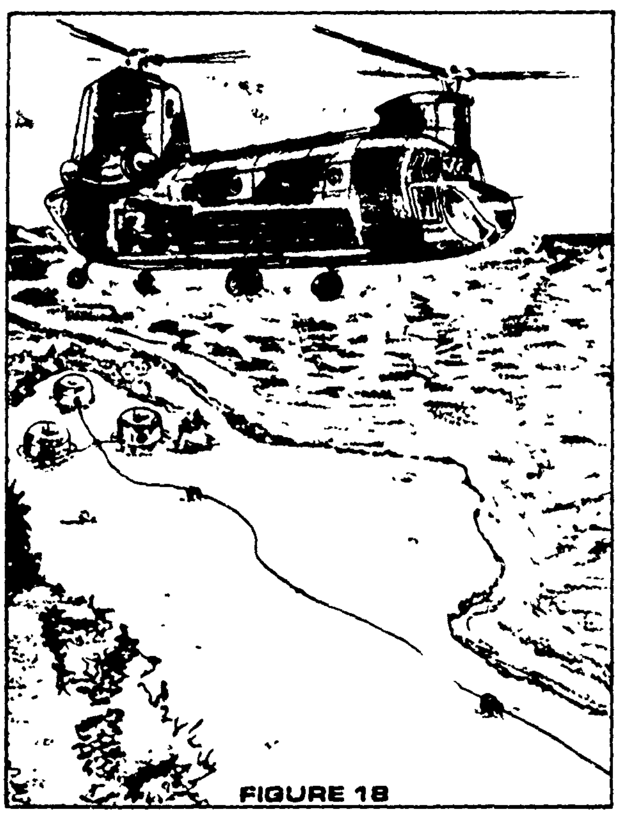


FIGURE 18

AIR TRANSPORTABLE PIPELINE SYSTEM

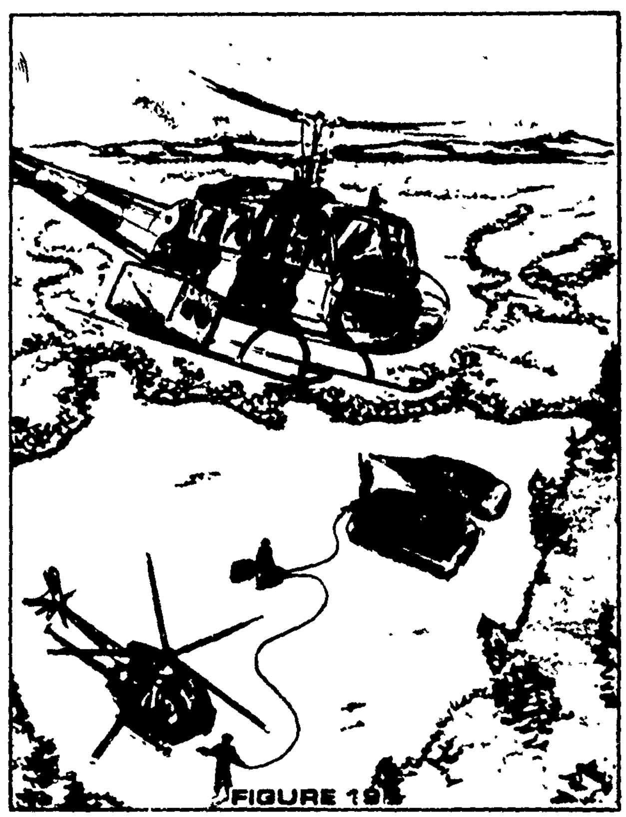


FIGURE 19

REMOTE AREA FUELING

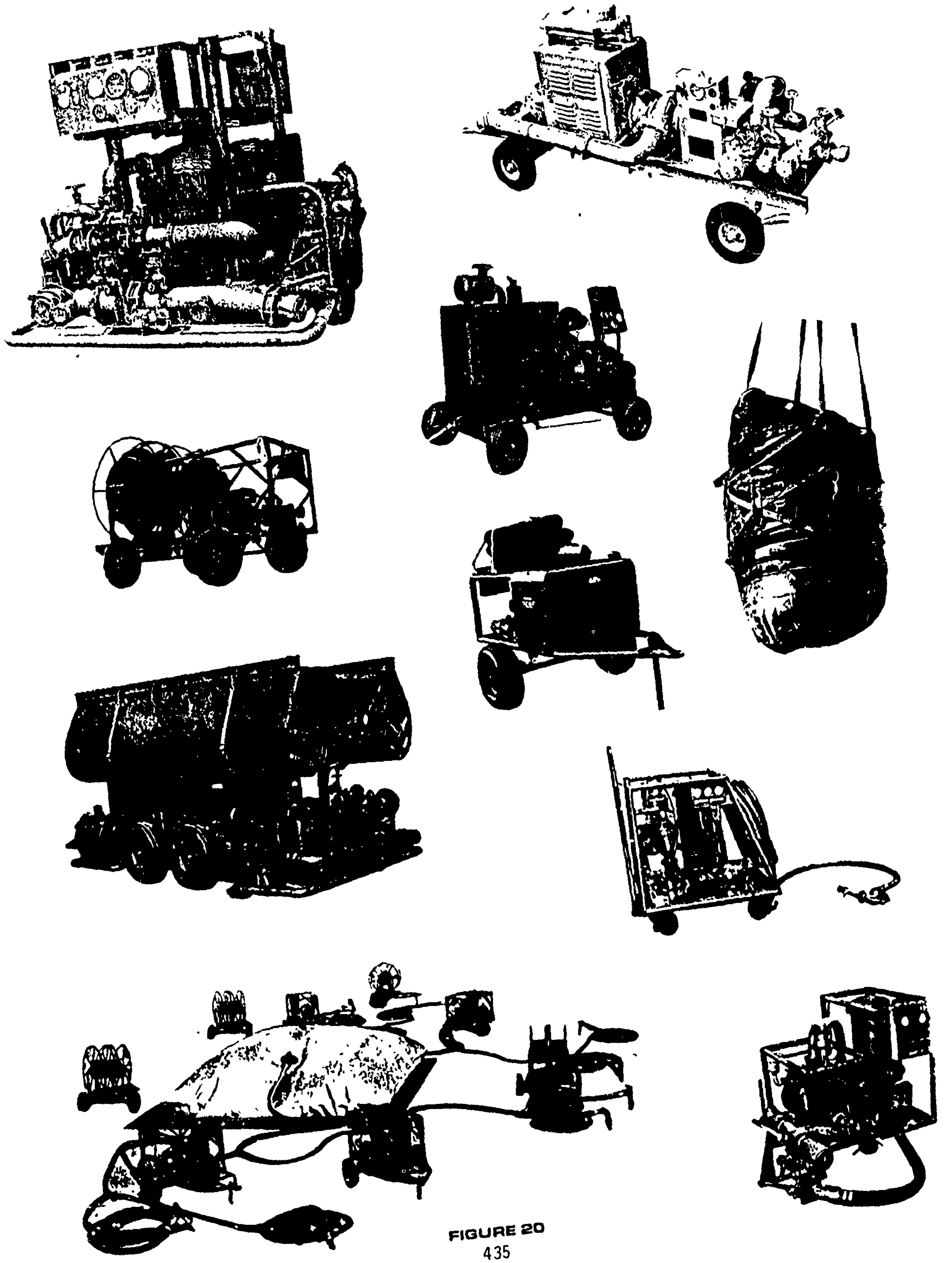


FIGURE 20

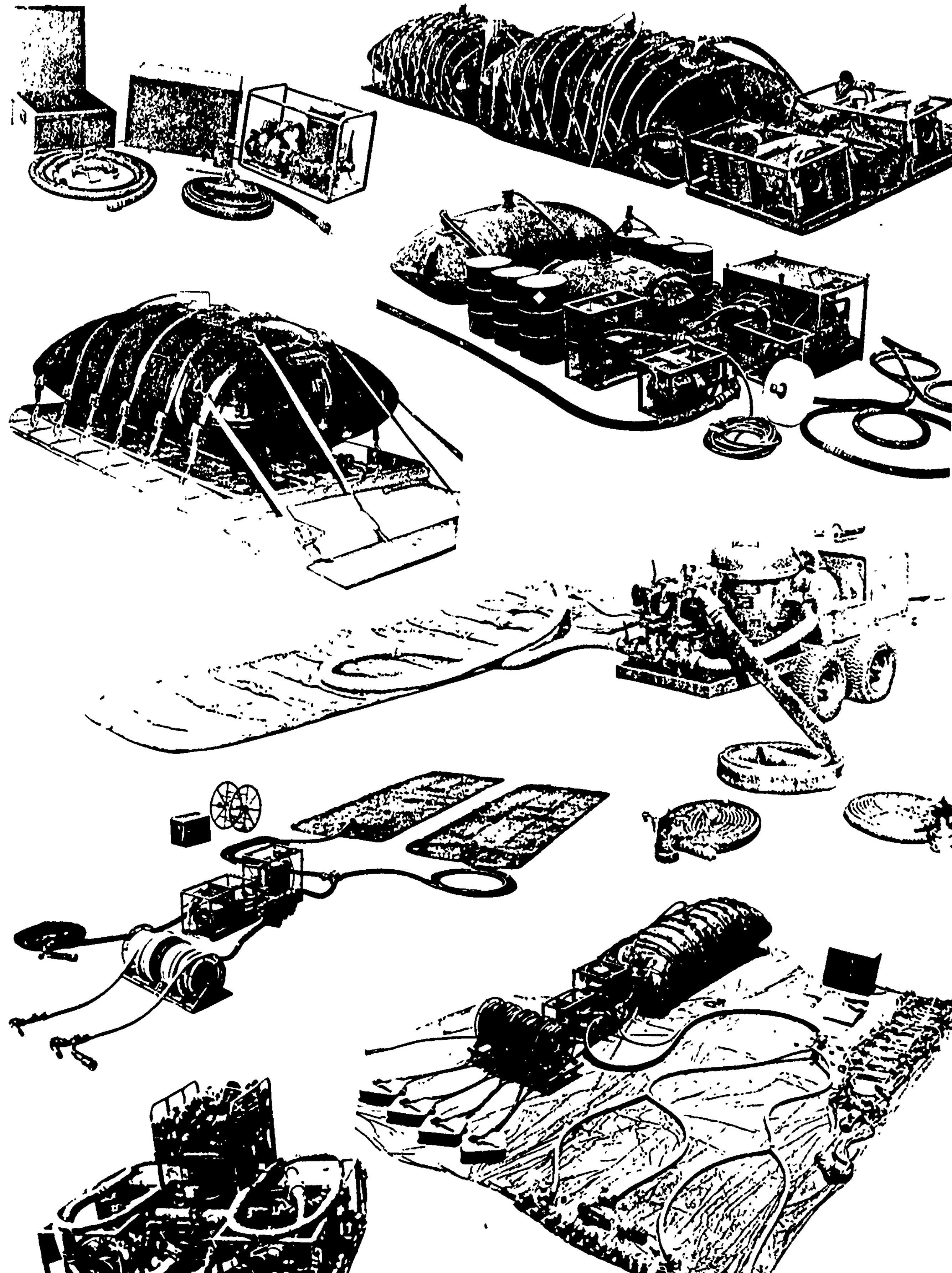


FIGURE 21

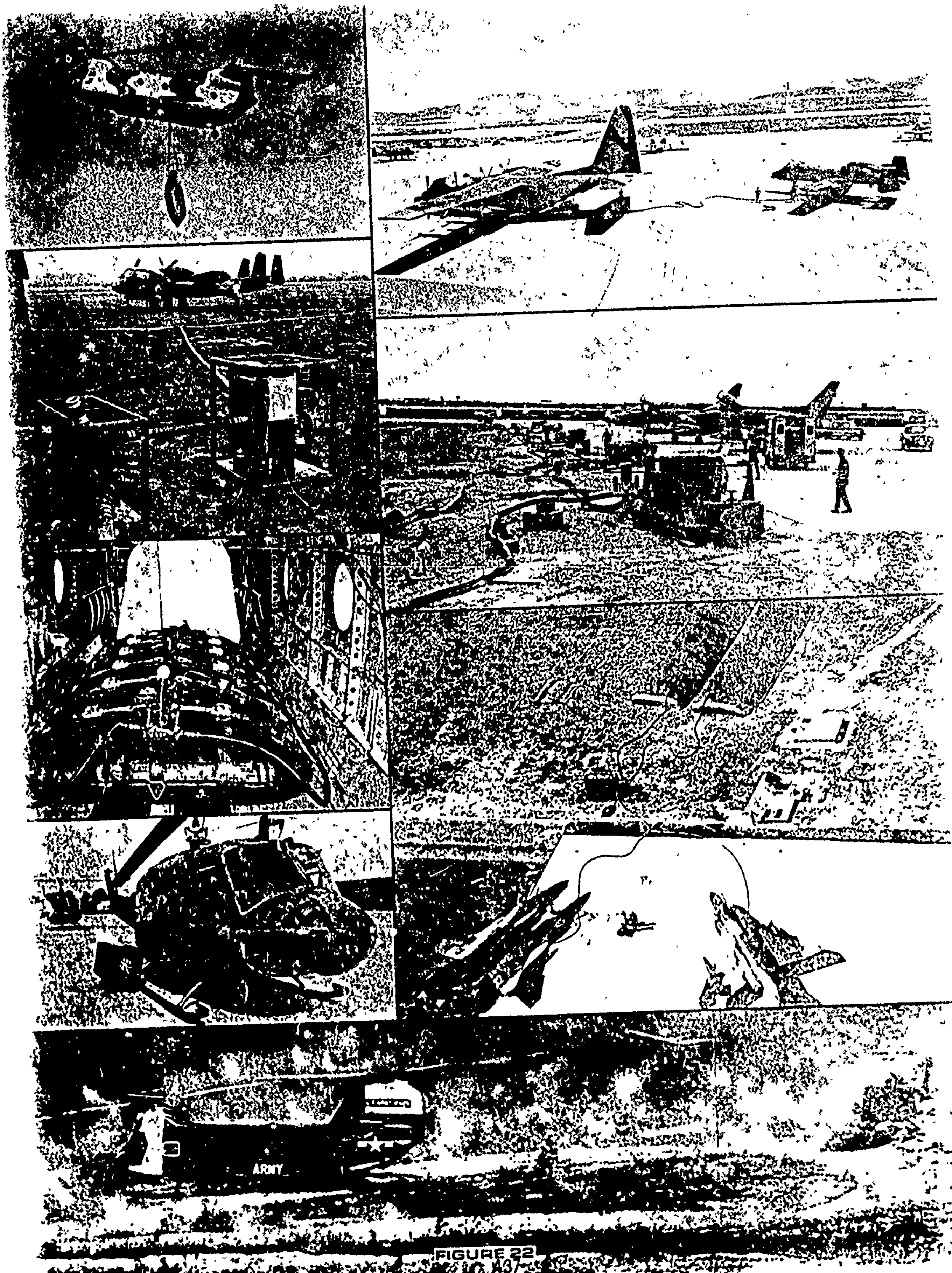
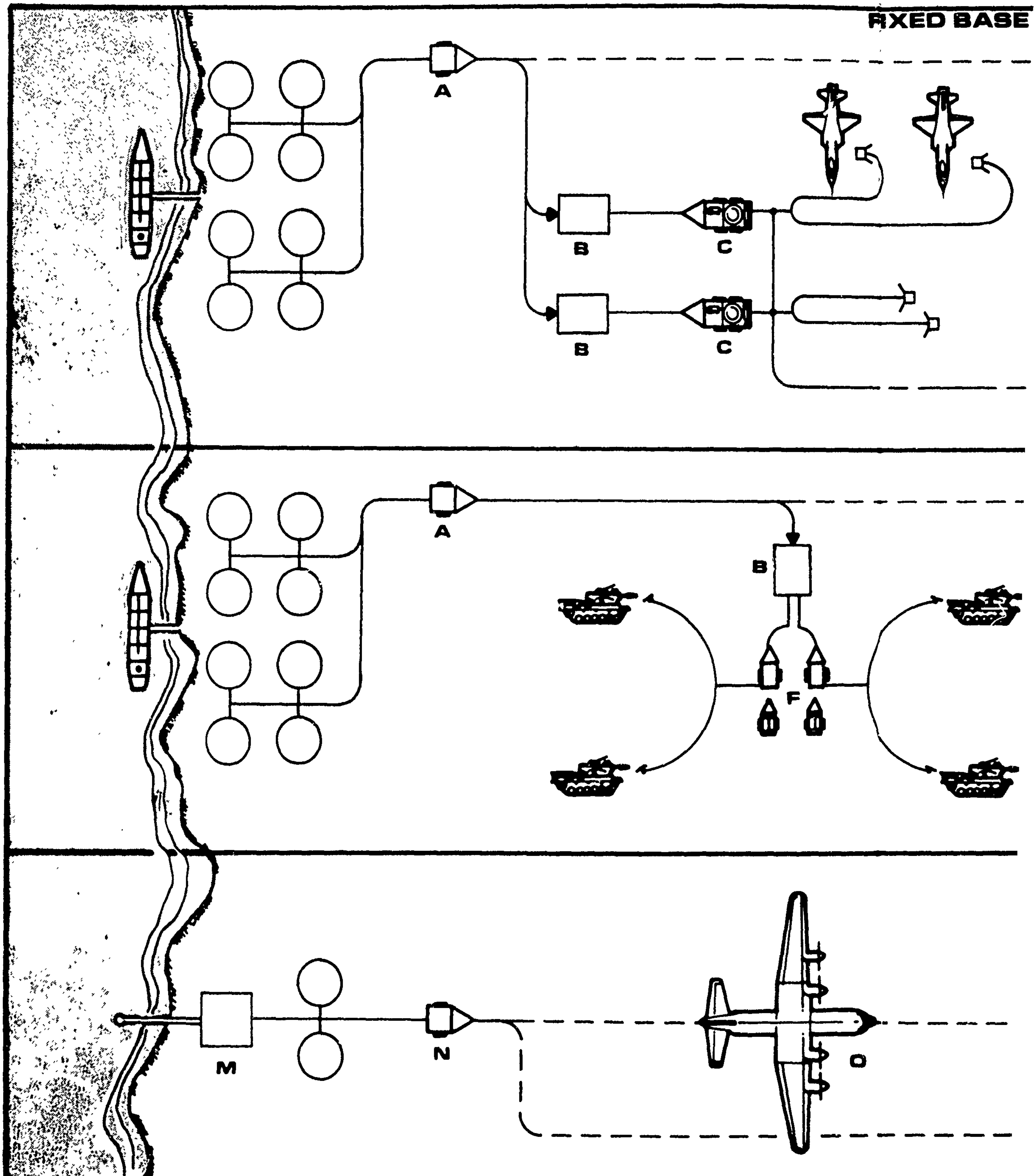
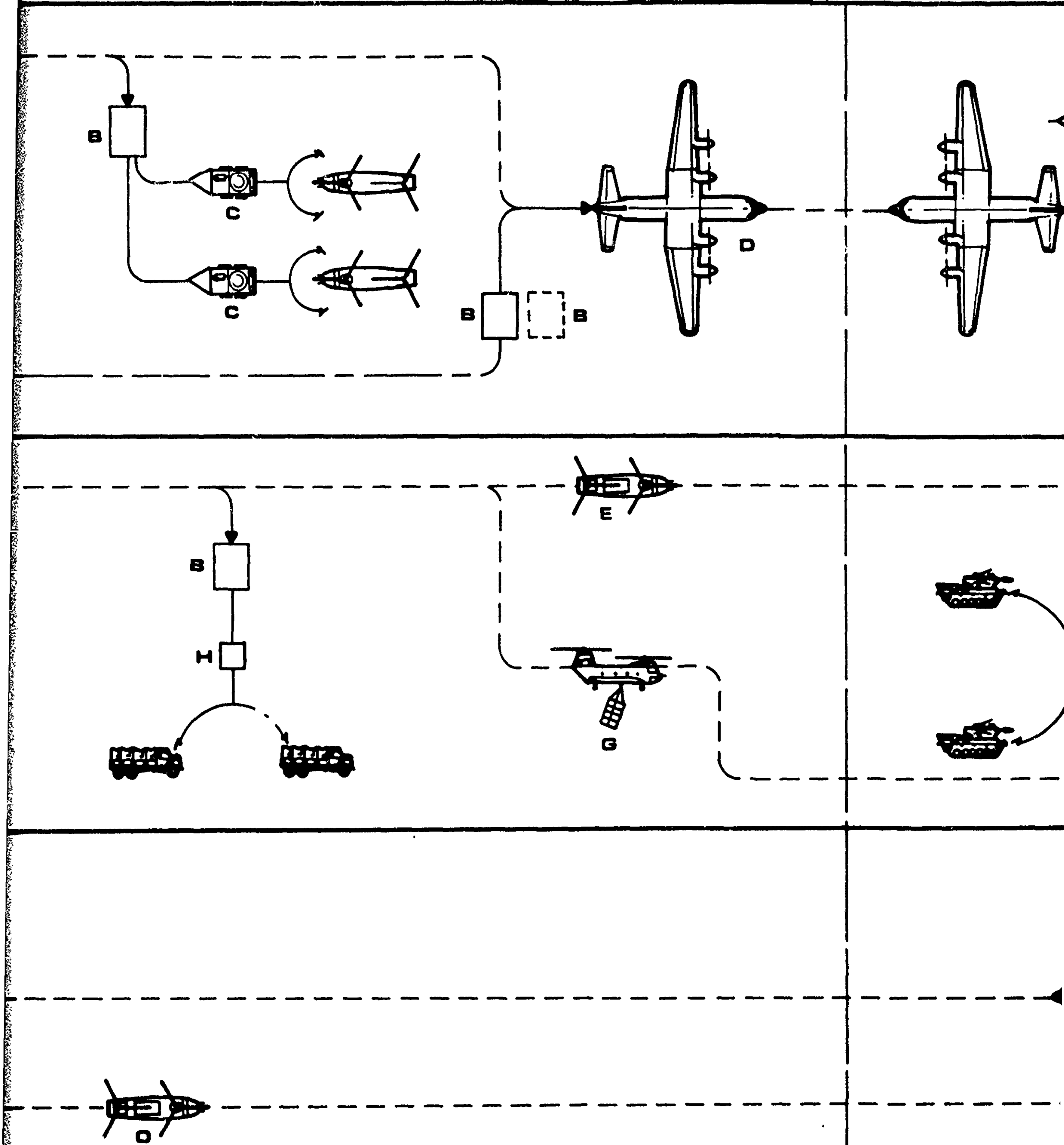


FIGURE 22



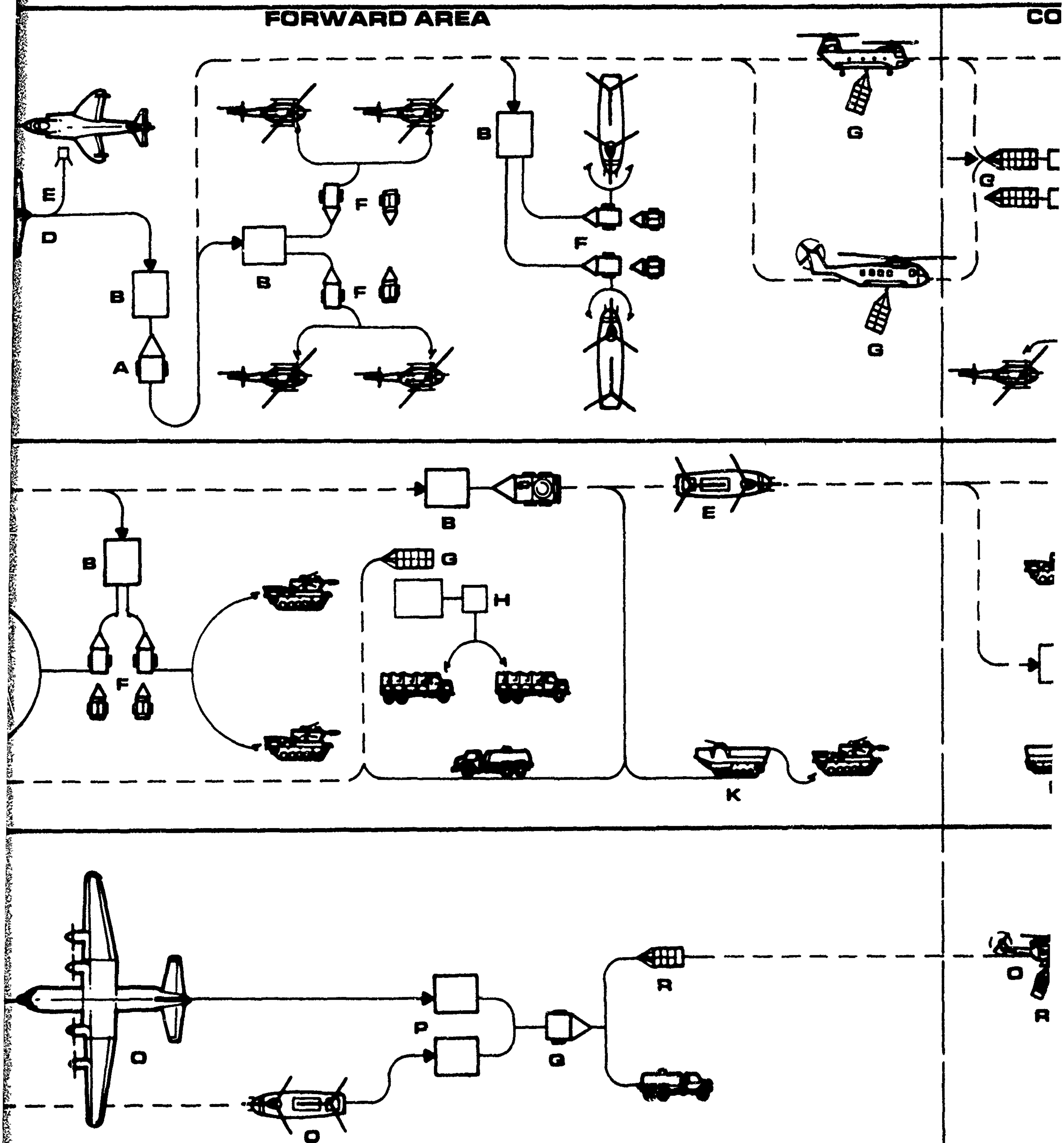
LEGEND	A - 600 GPM BULK FUEL PUMPER B - COLLAPSIBLE FUEL TANK C - 300 GPM HYDRANT SYSTEM	D - AIRBORNE BULK FUEL DELIVERY E - AIRBORNE FUEL SERVICING SYS F - 100 GPM FUEL SERVICING SYST

Figure 1



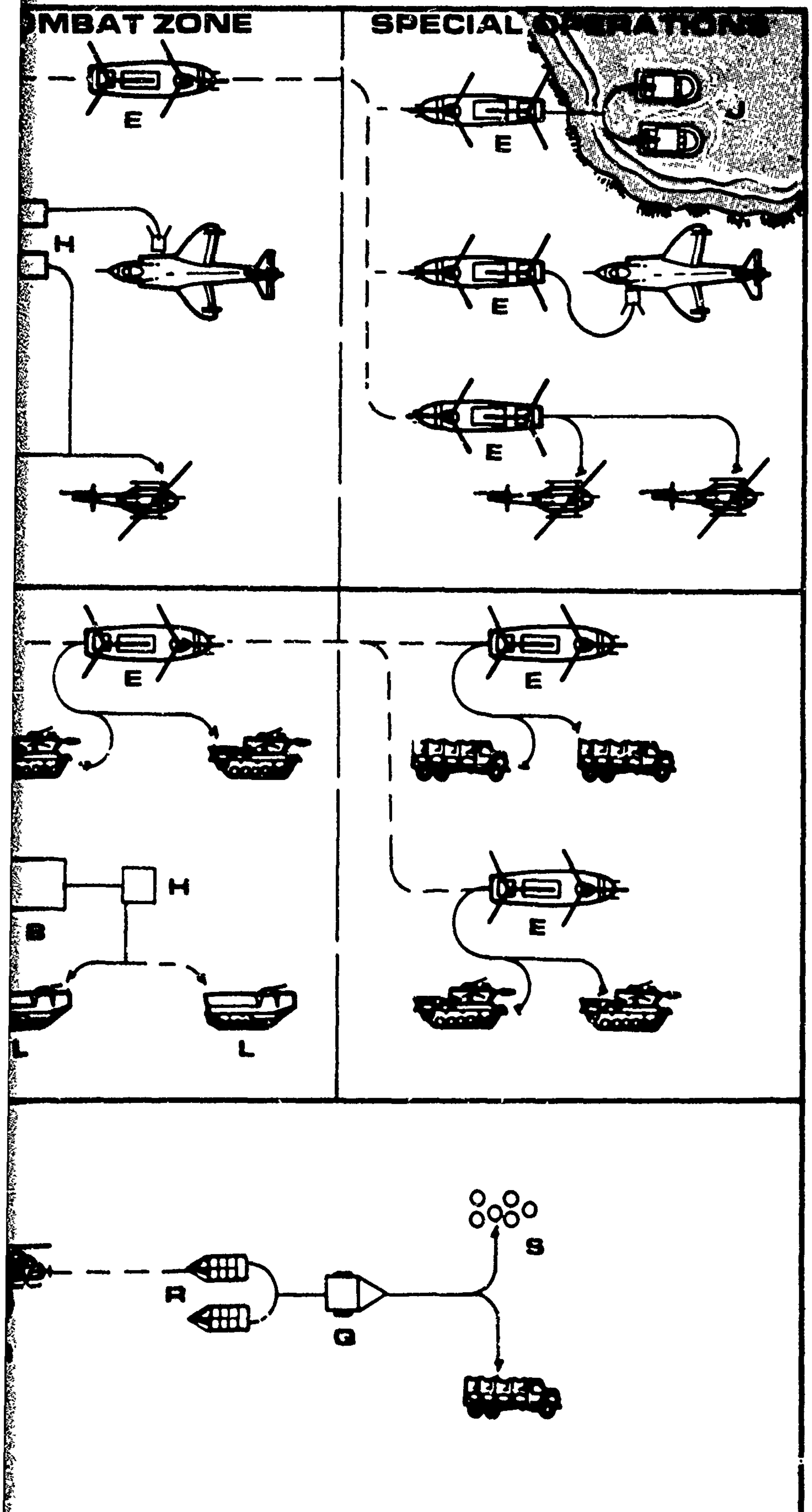
YSTEM	G - SLING TANK	K - ARMORED FUEL SERVICING SYST
EM	H - 50 GPM FUEL SERVICING SYSTEM	L - LANDING VEHICLE, TRACKED, PER
M	J - MARINE VESSELS	M - WATER PURIFICATION AND DESAI

2



STEM RSONNEL ALINATION	N - 600 GPM WATER PUMPER O - AIRBORNE WATER DELIVERY SYSTEM P - COLLAPSIBLE WATER TANK	Q - 100 GPM WATER PUMPE R - SLING WATER TANK S - WATER BARRELS

AIR



R | SYSTEMS AVAILABLE FOR JET FUEL, DIESEL, AV-GAS, MO-GAS, WATER, ETC.

LOGISTICS CORPORATION

DEW LINE - FUEL SUPPORT TO THE ARTIC

PRESENTED BY

LT COL C. A. (DICK) WEHMAN, USAF
DIRECTOR, LOGISTICS
DEW SYSTEM OFFICE

PRESENTED TO THE
INDUSTRY-MILITARY ENERGY SYMPOSIUM
21-23 OCTOBER 1980
SAN ANTONIO, TEXAS

DEW LINE BRIEFING

SLIDE 1 GOOD MORNING LADIES AND GENTLEMEN: I'M LT COLONEL WEHMAN, DIRECTOR OF LOGISTICS FOR THE DISTANT EARLY WARNING OFFICE LOCATED IN COLORADO SPRINGS, COLORADO.

SLIDE 2 THE PURPOSE OF MY BRIEFING IS TO GIVE YOU A SHORT OVERVIEW OF THE DISTANT EARLY WARNING LINE, COMMONLY REFERRED TO AS THE DEW LINE, AND DISCUSS ENERGY CONSERVATION/PETROLEUM PRODUCT RESUPPLY TO THE ARCTIC.

SLIDE 3 THE PRIMARY MISSION OF THE DEW LINE IS AIR SURVEILLANCE AND COMMUNICATIONS SUPPORT. TO ACCOMPLISH THIS, WE HAVE A SERIES OF THIRTY ONE INDIVIDUAL SITES STRETCHED ACROSS ALASKA, CANADA, AND GREENLAND TO TRACK ALL AIR MOVEMENTS IN THE ARCTIC. THIS INCLUDES BOTH MILITARY AND COMMERCIAL TRAFFIC.

SLIDE 4 THIS SLIDE WILL GIVE YOU SOME IDEA OF THE PHYSICAL LOCATION OF THE DEW LINE. IT IS GENERALLY BUILT ALONG THE 69TH PARALLEL AND COWERS SOME 4,000 MILES OF ARCTIC FRONTAGE. ALL OF THE SITES ARE WELL ABOVE THE ARCTIC CIRCLE TREE LINE AND LOCATED IN THE WASTE LANDS OF THE FRIGID ZONE. OF THE THIRTY ONE SITES, SIX ARE CONSIDERED AS MAIN SUPPORT, AND IN ADDITION TO RADAR DETECTION, ALSO PROVIDE LOGISTICAL SUPPORT AND OTHER SERVICES TO THE REMAINING 25 AUXILIARY SITES. TYPICAL MANNING FOR MAIN SITES IS FIFTY TO ONE HUNDRED EMPLOYEES, WHEREAS AN AUXILIARY SITE WILL NORMALLY BE MANNED WITH TWELVE PERSONNEL. THE RELATED PICTURES SHOWN HERE DEPICT FOUR OF THE SITES SCATTERED ACROSS VARIOUS PARTS OF THE LINE. NOTE THAT THESE WERE TAKEN ON OUR ONE DAY OF SUMMER AND IS NOT TYPICAL OF THE

OUTSIDE ENVIRONMENT IN THE ARCTIC.

SLIDE 5 THE HISTORY OF THE DEW LINE DATES BACK TO 1954. IT WAS COMPLETED IN MID 1957 AND BECAME OPERATIONAL IN FEBRUARY 1958. IN EARLY1960 THE GREENLAND SITES WERE ADDED AND ARE PART OF A TOTAL OF 31. YOU WILL NOTE THAT EXCEPT FOR THE PERIOD 1973-75, FEDERAL ELECTRIC HAS HAD THE CONTRACT TO OPERATE THE DEW LINE, AND THEY ARE THE CURRENT CONTRACTOR. NOTE: POINT OF CONCERN ABOUT THE DEW LINE IS ITS AGE. IT WAS ORIGINALLY INTENDED TO REMAIN OPERATIONAL TEN YEARS AND WE ARE NOW INTO THE TWENTY THIRD YEAR.

SLIDE 6 THIS SLIDE DEPICTS SOME OF THE MORE SIGNIFICANT SERVICES PROVIDED BY THE CONTRACTOR IN ACCORDANCE WITH OUR SPECIFIED STATEMENT OF WORK. BECAUSE OF THE COMPLEXITY OF EACH AREA I WILL ONLY ADDRESS PETROLEUM PRODUCT RESUPPLY AND WHAT STEPS WE IN THE DEW LINE OFFICE HAVE TAKEN TO COMPLY WITH ENERGY CONSERVATION PROGRAMS.

SLIDE 7 ARCTIC RESUPPLY OCCURS ONCE EACH YEAR DURING THE PERIOD OF 15 JULY TO 15 SEPTEMBER. WE NORMALLY LIKE TO THINK THAT WE HAVE A SIXTY FIVE DAY WINDOW IN WHICH WE WILL EXPERIENCE THE MOST FAVORABLE WEATHER. THIS MEANS WE WILL HAVE CLEAR, ICE-FREE WATER TO SAIL, ICEBERGS WILL BE OUT TO SEA, PACK ICE WILL BE BLOWN OFF-SHORE, AND TEMPERATURES WILL BE SUCH THAT IT PROVIDES A HABITAL CLIMATE IN WHICH TO WORK. THIS SUMMER WAS PERHAPS ONE OF THE BEST WEATHER CONDITIONS EVER EXPERIENCED. TEMPERATURES RANGED FROM THE MID FORTIES TO FIFTIES, AND FOR THE ARCTIC THAT HOT!!! TO ACCOMODATE SIMULTANEOUS RESUPPLY WE BREAK THE DEW LINE INTO THREE PARTS AND THESE ARE DEPICTED AS SHOWN HERE. WE ARE ALSO REQUIRED

TO WORK WITH EACH COUNTRY INDIVIDUALLY TO UTILIZE CONTRACT/ LABOR AND SERVICES WITHIN THAT COUNTRY WHENEVER POSSIBLE.

SLIDE 8 TO GIVE YOU A CLEARER PICTURE OF HOW OUR SEALIFT OF PETROLEUM PRODUCTS ACTUALLY WORKS, I HAVE SKETCHED OUT INDIVIDUAL SEA ROUTES USED BY OUR INDIVIDUAL CONTRACTORS IN EACH OF THE AREAS PREVIOUSLY NOTED. ALASKA IS SUPPORTED FROM THE WEST COAST PORT OF SEATTLE USING ALASKA PUDGET UNITED TRANSPORTATION COMPANY (APUTCO). THIS CONTRACTOR PROVIDES BOTH DRY CARGO AND PETROLEUM PRODUCTS AND SUPPORTS THE ENTIRE ALASKA COMPLEX INCLUDING THE DEW LINE. AS SHOWN, THEIR SERVICES TERMINATE AT POW-2. THE CANADIAN SITES IN WESTERN AND CENTRAL CANADA OFFER A BIT MORE CHALLENGE IN THAT WE ORIGINATE ALL CARGO AND PETROLEUM PRODUCTS IN HAY RIVER. THIS IS THE WINTER HOME OF NORTHERN TRANSPORTATION COMPANY LIMITED (NTCL) WHERE WE SHIP ALL COMMODITIES FOR ONWARD MOVEMENT TO THE DEW LINE. THE PECULIARITY HERE IS THAT NTCL MUST WAIT UNTIL THE MACKENZIE RIVER IS THAWED TO ACCOMMODATE BARGE TRAFFIC DOWN RIVER TO THEIR MAIN TERMINAL IN A VILLAGE CALLED TUKTOYAKTUK; TUK-TUK FOR SHORT. FROM THERE THEY FURTHER BREAK DOWN THEIR CARGO AND PETROLEUM PRODUCT ACCORDING TO INDIVIDUAL DESTINATION. IN A MOMENT I'LL SHOW YOU SOME OF THE WATERCRAFT SUPPORT USED TO CARRY OUT THIS SEGMENT OF DELIVERY. BASICALLY NTCL IS RESPONSIBLE FOR SERVICING 13 LOCATIONS.

THE EASTERN PART OF CANADA AND THE EAST AND WEST COASTS OF GREENLAND ARE SERVICED BY SHIPS ORIGINATING IN MONTREAL AND UNDER CONTRACT FOR DELIVERY BY THE CANADIAN COAST GUARD. THEY SERVICE A TOTAL OF EIGHT SITES. NOW, IF YOU HAVE BEEN COUNTING, THAT DOESN'T RESUPPLY ALL OUR SITES. WE DO IN FACT

HAVE A TOTAL OF FIVE ADDITIONAL LOCATIONS THAT ARE TERMED LANDLOCKED AND MUST BE SUPPLIED ANNUALLY BY AIRLIFT. THIS IS SOMEWHAT UNIQUE IN THAT OUR ICE CAP SITES IN GREENLAND ARE SUPPORTED BY SKI EQUIPPED C-130 AIRCRAFT THAT LAND ON SKIWAYS SMOOTHED OUT ON THE SNOW. OUR SITES IN CANADA ARE A BIT DIFFERENT IN THAT WE WAIT UNTIL EARLY APRIL AND SMOOTH OUT A RUNWAY ON FROZEN LAKES OR THE OCEAN, AND HAVE THE PLANES LAND ON ICE STRIPS 5,000 FEET IN LENGTH. TO ACCOMMODATE THIS OPERATION WE NEED A MINIMUM ICE THICKNESS OF FIVE FEET. AGAIN, THE C-130 AIRCRAFT IS THE PRIME MODE OF MOVEMENT.

LIDE 9-14 THE NEXT SERIES OF SLIDES IS SHOWN TO GIVE YOU SOME IDEA OF THE WATERCRAFT SUPPORT WE UTILIZE TO SERVICE OUR DEW LINE SITES. THIS PARTICULAR VESSEL IS THE U.S. PINNEBOG, OWNED BY THE AIR FORCE AND CONTRACTED TO NTCL FOR OPERATION. LIKEWISE, THIS NEXT VESSEL, A FLOATING DRY DOCK, IS OWNED BY THE AIR FORCE AND USED FOR SERVICING ANY VESSEL IN THE AREA NEEDING REPAIR. IN A SITUATION WHERE THE WATERCRAFT IS NOT OWNED BY THE AIR FORCE, THE USER PAYS FOR SERVICES RENDERED. THIS PICTURE IS ANOTHER SHOT OF THE SAME VESSEL BUT DURING THE WINTER SEASON. AGAIN THE SAME VESSEL BUT THIS TIME IT HAS THE PINNEBOG INSIDE FOR REPAIR. THIS PICTURE SHOWS AN NTCL OWNED SHIP, THE "FRANK BRODERICK" WHICH HAS A CAPABILITY OF HANDLING BOTH DRY CARGO AND PETROLEUM PRODUCT. IT IS USED TO SERVICE OUR DEW LINE SITES. THE LAST PICTURE IS ONE OF THE VESSELS USED TO SERVICE EASTERN CANADA AND GREENLAND. IT IS OPERATED BY THE CANADIAN COAST GUARD AND HAS A CARRYING CAPACITY OF IN EXCESS OF TWO MILLION GALLONS.

SLIDE 15 IN THE AREA OF FUELS MANAGEMENT, I'VE DEVELOPED A SLIDE TO SHOW YOU SOME OF THE PERTINENT FACTS RELATED TO OUR DEW LINE OPERATION. ANNUAL PRODUCT CONSUMPTION RANGES BETWEEN EIGHT AND NINE MILLION GALLONS. WE CURRENTLY USE ALL STEEL TANKS, HAVING REPLACED ALL REMAINING RUBBER BLADDERS THIS SUMMER. WE DO HAVE A VERY ACTIVE CONTRACT AIRLIFT EFFORT THAT FLIES DAILY IN THE ARCTIC, AND WE HAVE ESTABLISHED TWELVE REFUELING LOCATIONS ACROSS THE DEW LINE. SERVICING IS DONE WITH THE USE OF SPECIALLY DESIGNED REFUELING CABINETS SUITED TO THE ARCTIC WEATHER. MY LAST AREA OF FUELS MANAGEMENT IS IN THE AREA OF ENERGY CONSERVATION. SINCE THE ESTABLISHMENT OF BASELINE GOALS IN 1975, WE HAVE MANAGED TO REDUCE FUEL CONSUMPTION ON AN ANNUAL BASIS BY THE FOLLOWING FIGURES. THIS SPEAKS HIGHLY OF OUR PEOPLE AND THEY ARE CONTINUALLY STRIVING TO BETTER THIS RECORD.

SLIDE 16 MY LAST AREA OF DISCUSSION DEALS WITH A PROBLEM THAT IS PERHAPS UNIQUE TO ARCTIC REGIONS. IT DEALS WITH THE POUR POINT AT WHICH DIESEL FUEL ARCTIC PRODUCT WILL GEL OR NO LONGER FLOW. AT THE OUTSET OF THE DEW LINE OPERATION, WE USED A POUR POINT RATING OF -70 DEGREES FARENHEIT. IN RECENT YEARS THE ONLY PRODUCT AVAILABLE HAS BEEN A -60 DEGREE AND THIS YEAR WE ARE EXPERIENCING AVAILABILITY OF ONLY -50 DEGREE DIESEL FUEL ARCTIC IN CENTRAL CANADA. WE FEEL THAT THIS IS THE BARE MINIMUM DEGREE LEVEL WHICH WILL PROVIDE SUPPORT FOR OUR MISSION. THIS IS PARTICULARLY TRUE SINCE WE MUST PUMP OUR PRODUCT THROUGH TWO INCH PIPELINES OVER A DISTANCE OF UPWARDS TO SEVEN MILES. WE ARE CURRENTLY PLANNING ON PRECLUDING A GEL ACTION BY RESUPPLYING DAY TANKS AT LEAST EACH TWELVE HOUR PERIOD. HOPEFULLY THIS MOVEMENT WILL KEEP

THE PETROLEUM FLUID. IF NOT, THEN WE WILL HAVE TO GO TO SOME OTHER SOURCE SUCH AS HEAT TAPE, BUT THIS IS A COSTLY VENTURE TO UNDERTAKE. ADDITIONALLY, WE ARE WORKING WITH AFLC FUELS LABORATORIES HERE AND AT WRIGHT-PATTERSON TO FURTHER SATISFY THIS CONCERN IF IT IN FACT BECOMES A PROBLEM.

SLIDE 17 LADIES AND GENTLEMEN THIS CONCLUDES MY BRIEFING. IF THERE ARE ANY QUESTIONS I'LL BE HAPPY TO ANSWER THEM. AGAIN, THANK YOU FOR THIS OPPORTUNITY TO DISCUSS THE DISTANT EARLY WARNING PROGRAM WITH YOU.

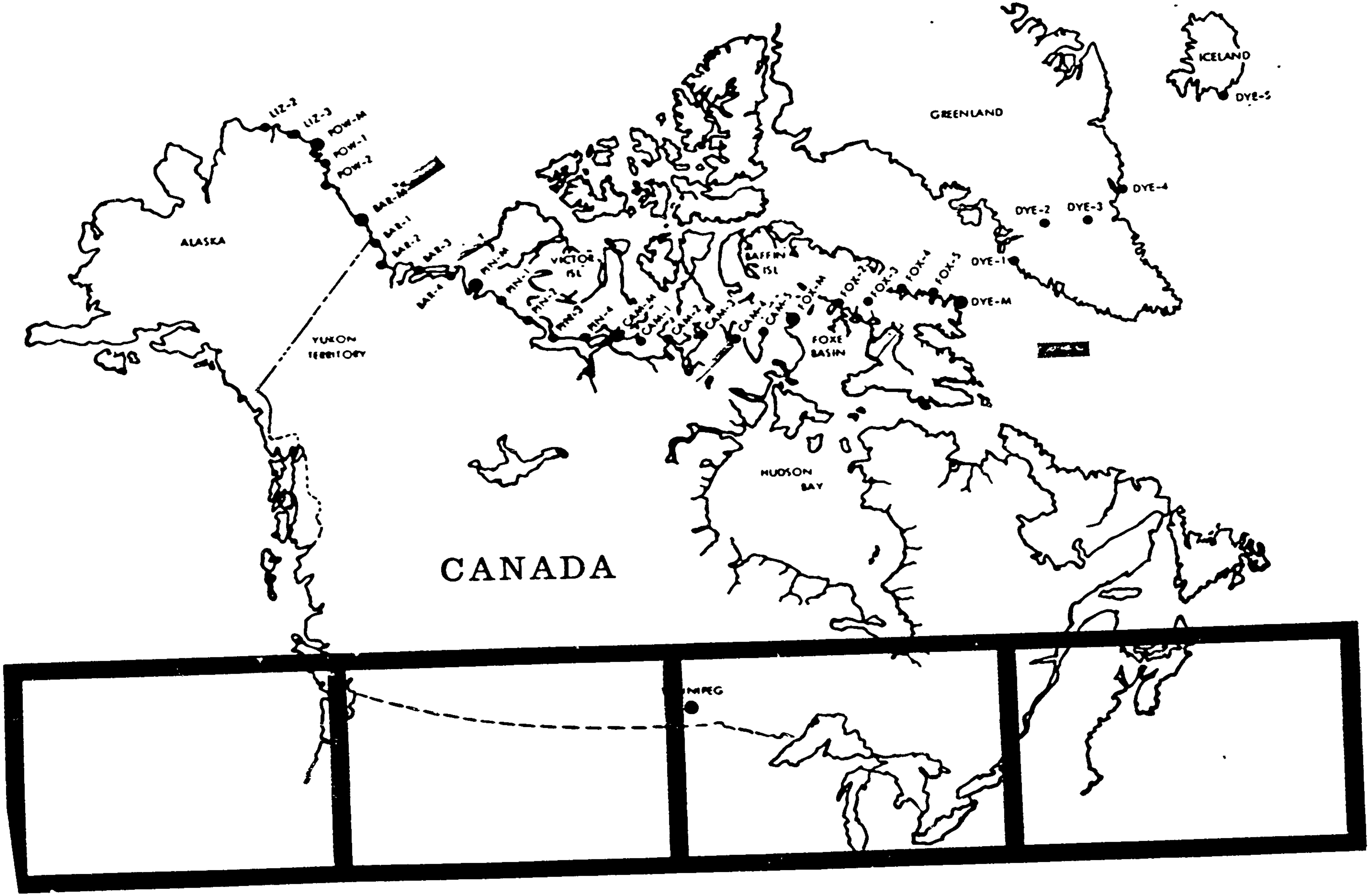
MISSION

AIR SURVEILLANCE

COMMUNICATIONS SUPPORT

SLIDE 3

DISTANT EARLY WARNING (DEW) LINE



SLIDE 4

MILESTONES IN HISTORY

1952	STUDY OF NORTH AMERICAN DEFENSES
DEC 1954	CONSTRUCTION COMMENCED
OCT 1956	FIRST SITE COMPLETED - BARTER ISLAND
JUL 1957	CONSTRUCTION COMPLETED
FEB 1958	TURNED OVER TO ADC
1960-61	DEW EAST SITES (GREENLAND) CONSTRUCTED
FY 1964-66	FEDERAL ELECTRIC (COST PLUS)
FY 1967-69	FEDERAL ELECTRIC (FIXED PRICE & INCENTIVE)
FY 1970-72	FEDERAL ELECTRIC (FIRM FIXED PRICE)
FY 1973-75	OMS, INC (RCA) (FIRM FIXED PRICE)
FY 1976-78	FELEC SERVICES, INC (FEDERAL ELECTRIC) (FIRM FIXED PRICE)
OCT 1978	CURRENT CONTRACT AWARD

ADC SLIDE 5

·SERVICES PPOVIDED

- OPERATE AND MAINTAIN RADAR
- OPERATE AND MAINTAIN COMMUNICATIONS
- PARTICIPATE IN DOD/NORAD EXERCISES
- SUPPORT OTHER COMMAND MISSIONS
- LOGISTICS & SUPPLY
- FOOD SERVICES
- TRANSPORTATION
- CIVIL ENGINEERING -- FIRE PREVENTION/SAFETY
- THIRD PARTY SUPPORT

SLIDE 6

FUELS MANAGEMENT

PRODUCT	CONSUMPTION (GALS)
DIESEL FUEL ARCTIC (DFA)	7,323,000
AUTOMOTIVE GASOLINE (MG2)	218,000
JET FUEL (JP-4)	1,250,000
	8,791,000

STORAGE

STEEL TANKS/RUBBER BLADDERS

5 YEAR PLAN

FY 80/81 ALL BLADDERS REPLACED 6,000/18,300 GAL STEEL SKID

REFUELING

12 SITES (INCLUDING POW-M)

TYPE REFUELERS

REFUELING CABINETS AR/75 (10 R/5s REPLACED)

FUEL CONSERVATION	GALLONS SAVED	PERCENT
FY 78	488,223	6.0%
FY 79	263,678	3.5%
FY 80	508,731	6.7%

SLIDE 15

DIESEL FUEL ARCTIC (DFA)

POUR POINT CHANGE
(AREA OF CONCERN)

* DFA P/50 RECEIVED AT 13 DEW LINE CANADA WEST SITES (FY 80) DUE TO NONAVAILABILITY OF DFA/P/60

* POWER PLANT DAY TANKS WILL BE RESUPPLIED AS OFTEN AS NECESSARY TO PRECLUDE FREEZING OF 2" PIPELINE DURING TEMPERATURE BELOW -50° F

* PIPELINE HEAT TAPE CONSIDERED AN ALTERNATIVE

SLIDE 16

FUEL SYSTEM

FOR

THE WORLD'S LARGEST AIRPORT

by

C. FRED NELSON - SENIOR FACILITIES ENGINEER

DELTA AIR LINES, INC.

PRESENTED AT THE INDUSTRY/MILITARY ENERGY SYMPOSIUM

OCTOBER 21 - 23, 1980 - SAN ANTONIO, TEXAS

On September 21, 1980, barely a month ago, the world's largest airport terminal complex began operations at Atlanta Hartsfield International Airport.* The opening marked the beginning of a new age in air transportation for the fastest growing region in the country. About 42 million passengers a year pass through the Atlanta facility, making it currently the world's second busiest, behind Chicago's O'Hare.*

The new 378-acre terminal complex, located midfield, about a mile from the old terminal, is designed primarily around the connecting passenger, which represents over 70 percent of the Atlanta traffic. Because of its geographical location, this hub is used to merge small passenger loads from Jacksonville, Birmingham, Memphis, Charlotte, and other cities in the region into profitable loads continuing on to Chicago, New York, Miami, Dallas, and elsewhere. There is no other more cost-effective means to serve the regional transportation needs. Without it, passenger fares on these route segments would be considerably higher and scarce fuel resources would be wasted.*

Atlanta, the beneficiary of these services, has not been slighted. Two parallel, connected main terminal buildings, covering 12.6 acres, serve local boarding passengers.* The 12,000-space parking area is considerably larger than the former parking area.* Spacious ticketing areas are designed to minimize passenger-waiting queues.* A separate international ticketing area serves the international terminal connected to the east end of one of the main buildings.*

Baggage carousels are located conveniently adjacent to all public and private transportation on the terminal's western side.*

Passengers move from the terminal to the four concourse areas through a central escalator system* that is three stories high.* Descending into the underground transportation mall, the passenger has the option of walking to the departure concourse, using the moving sidewalks at the sides,* or boarding the underground transit system. The furthest destination can be reached in five minutes.*

An escalator carries the passenger into the concourse* entering an avenue 30 feet wide,* with passenger lounges and boarding gates on either side.*

Convenient ticketing and information counters, as well as the other amenities, are available in each concourse.*

Up to 34 gates are located on each concourse and there are a total of 138 gates overall. The entire terminal complex was constructed at the center of the airport runway system to reduce taxiing time to a minimum.* The four concourses are spaced 300 yards apart, leaving enough unrestricted room between each of them to allow wide-bodied aircraft to pass two abreast between those already parked at gate locations.*

All gates are equipped with jetways, and Delta utilizes a unique aircraft parking device.* Two neon wands mounted on the concourse wall, when aligned by the pilot, locate the incoming aircraft on the proper centerline. Three lights mounted next to the wands control the aircraft movement. A gate agent on the ground monitors the approaching nose gear of the aircraft and switches the light from green to yellow when the nose gear is within about twenty feet of the proper stopping point. The pilot slows the aircraft and brings it to rest when the red light is illuminated. This places the aircraft in the proper position for servicing.* Delta's operation in Atlanta is the largest by a single airline at any airport in the world. Approximately 330 departures are presently scheduled per day, with an average servicing time of about 40 minutes.

Delta's gates are laid out such that four Boeing 727-type aircraft will park in the space provided for three Lockheed 1011-type aircraft. Because the cabin floor height from ground on the B-727 is less than the L-1011, the B-727 is parked further from the concourse to eliminate undesirable passenger loading bridge slopes. This placed the B-727 fueling point on a line approximately the same distance from the concourse as the L-1011 fuel point and enabled the construction of fuel hydrants on a common line for these aircraft. All hydrants provided are vertical risers off of the mains, with the exception of a dozen laterals provided for a future aircraft type and a few laterals for possible angle parking on the end gates.*

The new complex lies west of the airport's FAA control tower.* Due east, also between the runways, are located Delta's maintenance facilities* and the new midfield terminal support facilities.*

Immediately east of the tower is the new airport post office (not shown in the photo) and Eastern Air Lines cargo building. Next to Eastern's facility is the new 112,000 square foot Delta Flight Kitchen, the largest catering facility ever constructed.* Next is the cargo facility occupied by Delta, a 457,000 square foot terminal and the largest to be operated by a single airline.* Atlanta International is the center of an enormous cargo network, unloading half a billion pounds of air freight every day.*

This information has been offered to provide some perspective to the scope of an aircraft fueling system for the new complex. Additional considerations include the strategic location of Atlanta in Delta's route system* and Atlanta's position with respect to the major fuel supply pipelines serving Delta.

The majority of Delta's fuel in Atlanta is produced at Chevron's Pascagoula, Mississippi, refinery. Here, jet fuel is refined to ASTM Jet A, specifications and laboratory tested prior to shipment. After laboratory analysis confirms the fuel meets specifications, it is filtered by Chevron and released to Plantation Pipeline Company for transportation to Delta. Plantation's system stretches from Baton Rouge, Louisiana, to Washington, D.C., some 2,237 miles. The various lines carry gasoline, kerosene, and military jet fuel as well as commercial jet fuel.

At Pascagoula, the jet fuel is filtered as received through jet cleaning strainers which remove solid contaminants down to one ten-thousandth of an inch. From Pascagoula, the fuel travels to storage at Collins, Mississippi, then to Helena, Alabama, then to Bremen, Georgia, and finally to Austell, Georgia, where all fuel stored is destined for Hartsfield Atlanta International Airport. The fuel is laboratory tested again at Austell for specification compliance and shipped on demand to Delta. The fuel is filtered again at Bremen and at Austell, and the pipeline from Austell is internally epoxy-coated to insure cleanliness.*

At the airport, the fuel is filtered by the pipeline one last time before transference to Delta. Plantation's breakout station is located just west of the new fuel farm constructed by Eastern that is due north of the midfield complex. Eastern's facility, which will hold 296,000 barrels of jet fuel, when two tanks being relocated from their old facility are installed, serves the International Concourse and Concourses B, C and D at the midfield complex, except Delta, and their facilities are approximately the same size as Delta's.*

East of these facilities and north of the FAA tower lies the old Atlanta terminal.* Further east is Delta's fuel storage and distribution facility. The farm contains six 24,000 barrel tanks, four new 38,000 barrel tanks, and 34,000 barrels of storage in small tanks that served the old terminal. These old tanks are being placed back in service due to the Iraq-Iran conflict. A small diameter pipeline connects these facilities to a 10,000 barrel tank at Delta's maintenance facility.*

From Delta's new storage area the FAA tower can be seen over the old storage area,* as well as the midfield complex some 8,000 lineal feet away and 44 feet higher in elevation.*

Delta's storage area is protected by a passive foam-injection manifold fire protection system. The airport fire department can connect to a Siamese fitting on the manifold, open a valve, and direct AFFF fire extinguishing agent into any of the ten larger tanks. The tanks are built to API 650 specifications with a coned-down bottom and a center sump. They are internally epoxy coated to MIL-4556-D and the four new tanks externally painted with polyurethane. All tanks are equipped with internal floating roofs.*

Lines from receiving fuel filtration separately feed the six smaller tanks and the four larger tanks. Suction lines from the tanks are similarly separated* and piping is arranged to minimize interference. Public address system speakers and a multi-line telephone are mounted on the dike wall separating the tankage.*

Foam chambers are installed at the highest point on the tank shell walls.* Roof access manways are completely enclosed with guardrails for safety.* High pressure sodium vapor light fixtures are used to conserve energy.*

The inbound filtration system is located midpoint in the farm* and is equipped with separate lines of 1500 GPM and 1000 GPM horizontal coalescers, clay treatment, and filter/separators manifolded together, although either line may be used independently.*

These vessels, as well as all other vessels in the facility and all piping, are internally epoxy coated, conforming to MIL-4556-D. All new equipment is externally coated with polyurethane above ground and coated and wrapped to TGF-2 specifications below ground. API color coding is used throughout the facility. Two lines enter the filtration system, one from Plantation and the other a recirculation line from the hydrant system pump discharge manifold. All flow through the filtration system is monitored for flow, pressure, and temperature. The coalescers and filter/separators are equipped with automatic water drain valves and all vessels are monitored for high differential pressure. The system is designed to meet API 1581 Class B Group II qualifications.*

All tanks and all vessels in the facility are equipped with sump sampling fittings to perform daily checks for water or other contaminants.*

Sump drains are plumbed to a reclaim system that is a smaller version of the inbound system to clean up fuel and return it to storage.*

The new pump pad, Attendants' Building, emergency power units, and tender servicing island are located west of the tankage.*

Catwalks provide access to the pump lines installed on a concrete spill retainage pad.*

A common suction manifold feeds the eight 1000 GPM rated pump lines. The API 610, horizontal mounted, single stage, end suction, top horizontal discharge, bronze fitted, centrifugal pumps were specified to deliver 1000 GPM against a total head of 595 feet when driven at 3600 RPM. The pump motors were specified at a minimum 250 horsepower, ten starts per hour, NEMA Design B, with 60°C over 40°C motor insulation and labeled for Class I, Group D, areas. The specifications further required an overall efficiency of not less than 71 percent for the pump and driver when tested in accordance with National Hydraulic Institute standards. The pumps are preceded by 40 mesh basket strainers.

A 1250 GPM filter/separator unit is provided downstream of each pump unit, also qualified to API 1581, Class B, Group II. These units are equipped with automatic water drains, drain line heaters, differential pressure gauges, and water slug pilots that operate the combination water slug/flow control valves downstream of the units. Each pump line can be isolated for maintenance.

Modern airline fuel facilities operate on the pressure/flow concept. A lead pump is started on a fall in pressure sensed at the discharge manifold. Additional pumps are started in response to flow measured by a differential pressure meter. In this system, excess flow over that demanded by the hydrant system is bypassed from the discharge manifold to the suction manifold through a hydraulic control valve installed in a bypass line. This bypass line separates the eight pump lines into two groups of four each that can be utilized in unison or separately.* The common discharge manifold branches into two separate 16" transmission lines that loop Delta's gates at the International Concourse and Concourses A and B.* Additional branches feed the two position tender loading island, the Fuel Test Room in the Attendants' Building, the 10,000 barrel maintenance base tank, and a recirculation line through the inbound filtration system.*

In case of an interruption in normal power, diesel engine driven generator sets provide backup emergency power. A small 25kw unit is started through an automatic transfer switch, on a loss in normal power, to provide immediate control power and lights.* Two larger 500kw units are started manually, after determination of the power loss problem,* from control panels located inside the Attendants' Building Equipment Room. These units are capable of operating at least four of the main pumps.*

Two low voltage motor control centers, bolted back to back, provide the power distribution system.*

Located inside the Attendants' Building Control Room is a micro-computer operated control system for the facility. A graphic display panel provides visual monitoring of the storage facilities, filtration systems, and pump lines. Typical control points include high and low tank levels, tank valve positions, inbound filtration flow paths and alarm conditions, and pump line operation and alarm conditions.* Recorders monitor inbound and outbound fuel flow, pressure, and temperature. A digital readout of fuel level or temperature in any of the ten large storage tanks is available.*

A control panel permits the Fuel Attendant to open and close tank valves remotely or to start and stop pumps manually.*

A CRT and line printer are used for system monitoring and control.* Either keyboard can access the computer for live control, to change operating parameters, or to produce statistical information. The hard copy event logging printer is designed to assist in troubleshooting problems.* A P.A. System broadcasts alarms to the outside.

Adjacent to the Control Room is the Technicians' Shop, used for components repair,* and the Test Room, used for performance testing of repaired components and condition testing of filtration equipment elements.*

Atop Concourse A is Delta's Ramp Control Tower which controls operations on the International Concourse, Concourse A, and the west side of

Concourse B.* Ramp fueling operations are monitored from a position in this tower, and the agent has a duplicate of the CRT in the Attendants' Building. The fuel system could be controlled from this position, if desired.*

Delta's hydrant system incorporates a unique emergency fuel shut-off system. Motor-operated isolation valves are installed on the hydrant piping about every four gates on Concourses A and B, and on either side of all gates at the International Concourse. The valves are controlled by a supervised alarm system which is monitored in the Ramp Tower on a graphic display panel.* Tripping a pull station located at any gate position causes the valves located on either side to close and stop the flow of fuel.* Surge protection is provided in the isolation valve pits to control the resultant pressure changes. If a valve fails, the system automatically closes the next valve in line. If that fails, the system stops the pumps at the farm. Remote closing of the valves is possible from the tower console.*

The new hydrant servicing vehicles are equipped with side fueling hose reels to service B-727 size aircraft,* while lift platforms are used for the larger aircraft. The ground connection hose reel swivels about 200 degrees to facilitate attachment to the hydrant valves. Delta utilizes a hose end coupler pressure regulation and flow control system. Residual pressure at the system hydrants is maintained at about 120 psi.* The hydrant vehicles are also equipped with a ground equipment fueling system.*

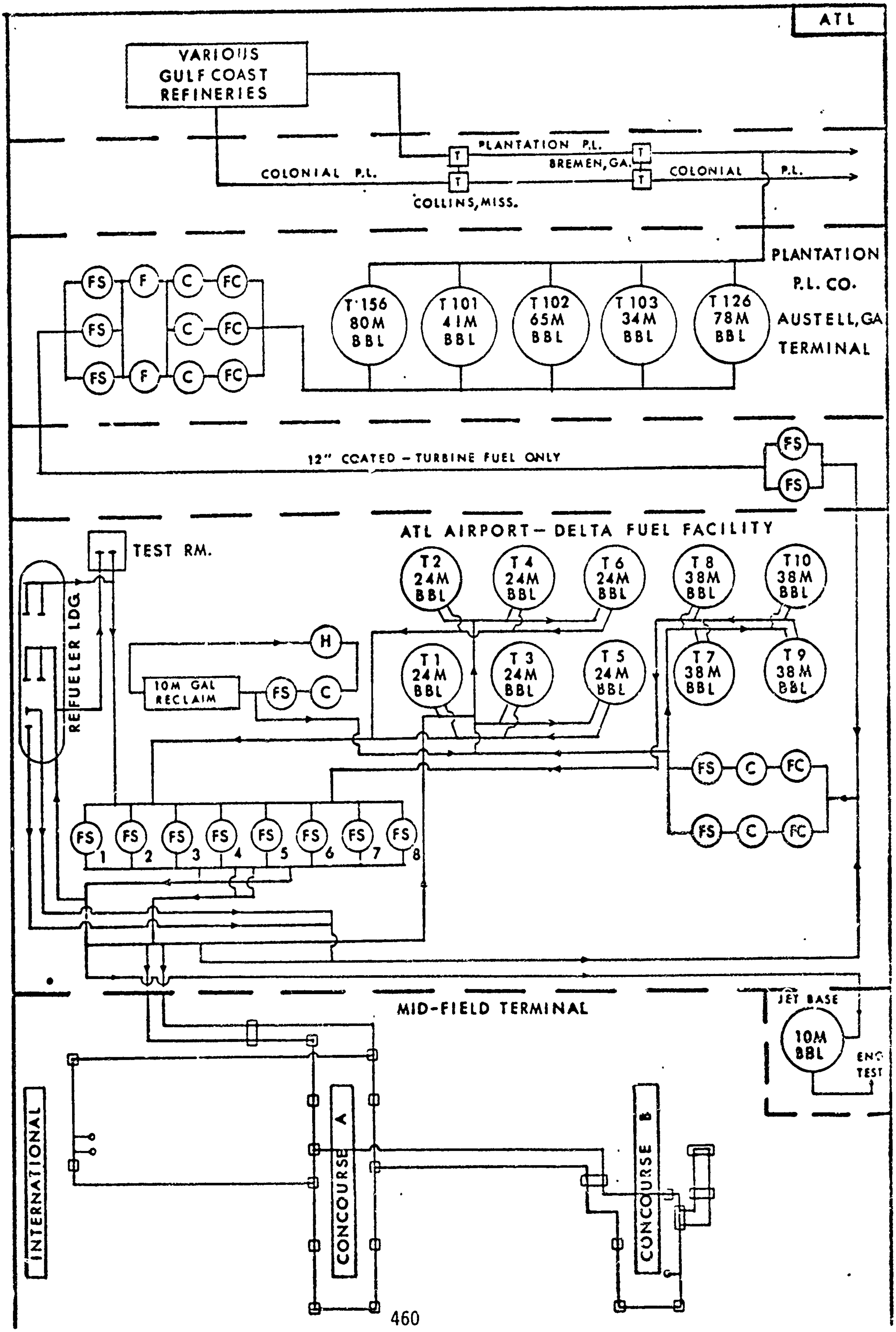
The major emphasis behind the move to midfield was to eliminate delays caused by aircraft movements across Runway 8/26, adjacent to the old terminal, to and from the south runways. The new facility permits aircraft to taxi in either direction on the ramp to departure runways on both sides of the terminal. The southernmost runway is used almost exclusively for landings.

The Delta midfield fuel system cost about $12 million and was built under fourteen different contracts with considerable minority participation in design and construction. It is a credit to the design engineers, Robert & Co. Associates, and to the major contractor AMC-Heard, that both the Delta and Eastern projects were designed and constructed within about 24 months. The Delta project was completed within budget and the system operated without interruption on opening day. In fact, it had to, since there was no backup system available.

The fuel lifting pattern for Atlanta just prior to opening the new terminal and after has been analyzed to see what savings could be attributed to the move. Delta's daily Atlanta full boardings between September 7 and 20 were 850,798 gallons per day. Between September 21 and October 1 the boardings dropped to 788,553 gallons per day, for a difference of 62,245 gallons, or 7.3%. Although other factors may have had some effect on these apparent savings, we feel the major portion would be attributed to the midfield move.*

Despite the size of the new facility, allowances have been made for future expansion. Plans include a fifth concourse, a second international terminal, a fourth runway, and additional subway positions in the transportation mall, allowing the airport to accommodate 75 million passengers a year.*

Finally, a comment about deregulation. Delta's and Eastern's passenger operations at Atlanta International are the largest in their respective systems, and each company is the other's strongest competitor. However, because of the connecting traffic characteristics in Atlanta, each company may also be the other's largest customer. This contradiction is also visible in the two fuel systems that serve Atlanta, which are physically connected where the lines cross north of Concourse C. This connection enables Delta and Eastern to transship fuel between each other's farms and further insure that, in Atlanta, we'll keep them flying.


ATL
VARIOUS GULF COAST REFINERIES
PLANTATION P.L.
BREMEN, GA.
COLONIAL P.L.
COLONIAL P.L.
COLLINS, MISS.
PLANTATION P.L. CO. AUSTELL, GA TERMINAL
T 156 80M BBL
T 101 41M BBL
T 102 65M BBL
T 103 34M BBL
T 126 78M BBL
12" COATED – TURBINE FUEL ONLY
ATL AIRPORT – DELTA FUEL FACILITY
TEST RM.
REFUELER LDG
10M GAL RECLAIM
T2 24M BBL
T4 24M BBL
T6 24M BBL
T8 38M BBL
T10 38M BBL
T1 24M BBL
T3 24M BBL
T5 24M BBL
T7 38M BBL
T9 38M BBL
MID-FIELD TERMINAL
JET BASE
10M BBL
ENG TEST
INTERNATIONAL
CONCOURSE A
CONCOURSE B

TACTICAL
IN-SHELTER REFUELING
CONCEPT

BY
WALTER WILL
COMMAND FUEL FACILITIES ENGINEER
HQ US AIR FORCES EUROPE

PRESENTED FOR

INDUSTRY-MILITARY ENERGY SYMPOSIUM
SAN ANTONIO, TEXAS

21-23 OCTOBER 1980

INTRODUCTION

Refueling of tactical aircraft in the NATO countries has been for many years accomplished by utilizing refueling trucks either by means of over-wing refueling or through the single point pressure nozzle.

Aircraft have been parked on large concrete aprons which could easily be refueled from trucks.

As part of the requirement for survivability a large concrete shelter construction program was started several years ago to fully protect the aircraft while it was on the ground being serviced and being made combat ready.

One important factor was initially overlooked in the total concept of survivability: the refueling of the aircraft inside the shelter. Many airwings of NATO countries refuel their aircraft with the refueling truck parked in front of the shelter with doors left open.

These refueling methods, however, will not survive in case of an attack.

TECHNICAL COMPARISON OF EXISTING AIRCRAFT REFUELING SYSTEMS WITH PROPOSED IN-SHELTER REFUELING CONCEPT.

First Generation of Fueling Systems:

Horizontal steel tanks in sizes up to 100 m^3 (26,000 gal) have only one meter of earth cover; piping has a minimum coverage of 0.8 to 1.0 meter; filter/manifold stations and truck fill stands are only splinter protected.

When the refueling road or perimeter road is damaged, the fueling truck will not be able to reach the aircraft in time for servicing. With temporary repair of craters, a fully loaded 5,000 gal refueling truck driven over a repaired road section will sink in (especially in winter time) and block all on-going through traffic. Furthermore, these trucks have a very low survivability when exposed during air attack.

Repair of these Refueling Systems:

It is very difficult and will take days in case of damage because these systems are not standardized, components are not interchangeable and spare parts are not readily available for all equipment.

System will be out of operation too long and can no longer support the assigned mission.

Second Generation of Fueling Systems:

Vertical underground steel storage tanks in standard sizes (1250, 2500, and 5000 m^3) are embedded with reinforced concrete bottom, wall and roof and are considered semi-hardened. All piping and truck fill stands are only splinter protected and also vulnerable as described under the first generation system.

An improvement was achieved in the second generation family when the semi-hardened storage tanks were provided with the pressure type dispensing for hot refueling of aircraft. At that time, vulnerability of aircraft while hot refueling was not a real concern since refueling in shelters with JP4 was not envisioned due to safety considerations. In August 1977, SHAPE informed us that NATO would no longer fund hot refueling projects since future policy will dictate that aircraft be refueled in a protected environment. They also requested that USAFE develop a proposal which could implement this policy.

Future Proposed Refueling System:

Fuel storage in a squadron shelter area normally will consist of standardized semi-hardened tanks as described above. Fuel is received through the on-base pipeline distribution system, which also interconnects with the other storage areas.

Design of the USAF Type IV Rapid Refueling System, with the exception of the hot refueling dispensing pits, will be used as a basic system and connected to a proposed 8 inch looped underground pipeline. From this 8 inch looped line a single 4 inch pipe extends inside the shelter and connects to the pantograph type dispensing system. When the fuel dispensing hose is connected to the aircraft refueling receptacle, fuel will flow into the aircraft the moment the "dead man" switch is pushed. When the refueling operation has been completed and the "dead man" switch is released, the refueling control valve upstream of the pantograph will close automatically. The fueling pumps on the storage tanks are equipped with flow switches which shut off the electric motor automatically when there is no more fuel flowing through the pipeline.

REQUIREMENT FOR AIRCRAFT REFUELING IN A PROTECTIVE ENVIRONMENT.

First recognized in 1977 when SHAPE informed USAFE that hot refueling systems are no longer supported due to vulnerability of aircraft during refueling periods.

Over 50% of existing storage/dispensing systems in NATO countries built in the 1950-1970 time frame are outdated due to nonstandardized and obsolete equipment in use. These systems will not survive in case of attack.

NATO/SHAPE requested that prior to the adoption of in-shelter refueling as a minimum military requirement, a safety study be conducted.

USAFE requested P-341 funds of $531,000 in December 1978 and USAF approved the project in amount of $300,000 to construct a prototype in-shelter refueling system in January 1979 at Spangdahlem AB, Germany.

The prototype system with pipeline loop and dispensing points in four shelters was completed in September 1979 and demonstrated to representatives of SHAPE, HQ NATO and various NATO countries.

After an experimental period of 12 months and accomplishment of safety improvements this prototype in-shelter refueling system is now in daily use.

OPERATION OF THE PROTOTYPE IN-SHELTER REFUELING SYSTEM.

Capability:

The two refueling pumps from a standard tank with a capacity of 110 cbm/hr and 115 m head each will be used to feed the shelter pipeline loop.

When the first aircraft inside a shelter is connected to the pantograph and the "dead man" switch is actuated, fuel begins to flow due to the static pressure head in the line. Pressure drops and the first pump automatically turns on, actuated by the minimum setting on the pressure switch. Should a second or third aircraft be connected for refueling while the first aircraft is still being serviced, then the second refueling pump is automatically actuated by the flow switch.

Four aircraft having a flow rate of approximately 985 l/min (300 gpm) each can be serviced simultaneaously with an operating pressure of not to exceed 3.52 bar (50 PSI) at skin of aircraft.

Survivability:

From a survivability point of view the underground looped pipeline and dispensing points inside the shelters assure an optimum of protection and operational assurance that aircraft can be refueled under all possible conditions.

Standardization of these new systems, interchangeability of equipment and availability of spare parts will assure that the system can be repaired very quickly.

The Army Corps of Engineers conducted a test on the effects of explosions on underground pipelines. The conclusion from this study was that a pipeline is not expected to rupture if the pipeline is located one crater radius or more from point of impact.

If the pipeline is damaged, repairs can be made in approximately two hours. To assure a quick response it is proposed to store inside the shelters standard pipe sections in different lengths as spool pieces with quick pipe couplings for repair of a damaged section without welding. Tools such as pipe cutters will also be stored inside the aircraft shelter.

Flexibility:

The pipeline will be configured so that fuel may be pumped in either direction through isolation valves which will limit the numbers of shelters affected in the event the pipeline is damaged. The flexibility of the system is further enhanced by interconnection of the Type IV Refueling Systems with the on-base distribution pipeline or by pumping directly from the NATO pipeline into the shelter loop in case of emergencies.

ESTABLISHMENT OF SAFETY CRITERIA AND ENGINEERING GUIDELINES.

Prior to the establishment of engineering and design criteria for refueling of tactical aircraft inside shelters with doors closed, NATO/SHAPE requested that a safety study be conducted.

During the ninth meeting of NATO (MAS) aviation POL Handling Equipment (PHE) Working Party 10-19 October 1979 in London it was agreed by all nations that a panel of expert engineers of seven NATO nations be established. The US as the leading nation was requested to provide the chairman of the panel. HQ USAF nominated Mr Will of USAFE to be the chairman of the panel.

Terms of reference for the in-shelter refueling panel is to assist and to improve NATO interoperability by establishing parameters for in-shelter refueling. The panel is to:

- establish the minimum safety criteria with particular reference to flammability and toxicity hazards,

- establish general engineering guidelines to meet minimum operational requirements of the NATO nations concerned. The guidelines will be flexible and will recognize existing and various projected fueling systems for in-shelter fueling and recommend new systems where required.

PRELIMINARY RESULTS OF FIELD TESTING.

A number of tests have been completed to verify the fuel vapor concentration during refueling of aircraft inside shelters with closed doors.

It was found that the explosive mixtures during aircraft refueling are being influenced by:

- chemical characteristics of the fuel flashpoint and vapor pressure

- temperature of the vapors inside the aircraft fuel tanks and the increased pressure on the tanks as a result of heat build-up during flights and also external temperatures

- temperature of the fuel being pumped into the aircraft

- turbulence of the fuel inside the aircraft tanks during refueling operation.

Attached figures No 1, 2, 3 indicate that only in the immediate vicinity of the aircraft vents does the vapor concentration reach a danger level.

Figure No 4 is a typical illustration showing the danger zones around the aircraft vents. It should be noted that the danger level of 50-100% LEL (lower explosive limit) is only within a radius of approximately two meters around the aircraft vents. Furthermore, this LEL concentration is only present during the few minutes of refueling as fuel vapors dissipate rapidly.

Another significant finding was that in tropical climates where the temperature of the fuel and the air temperature inside the shelter is equal or greater than 30°C, the vapor concentration at a distance of approximately two meters from the aircraft vent will drop rapidly to approximately 50% LEL. From that point on the dilution process with air is considerably slower than that observed in cooler climates.

CONCLUSION.

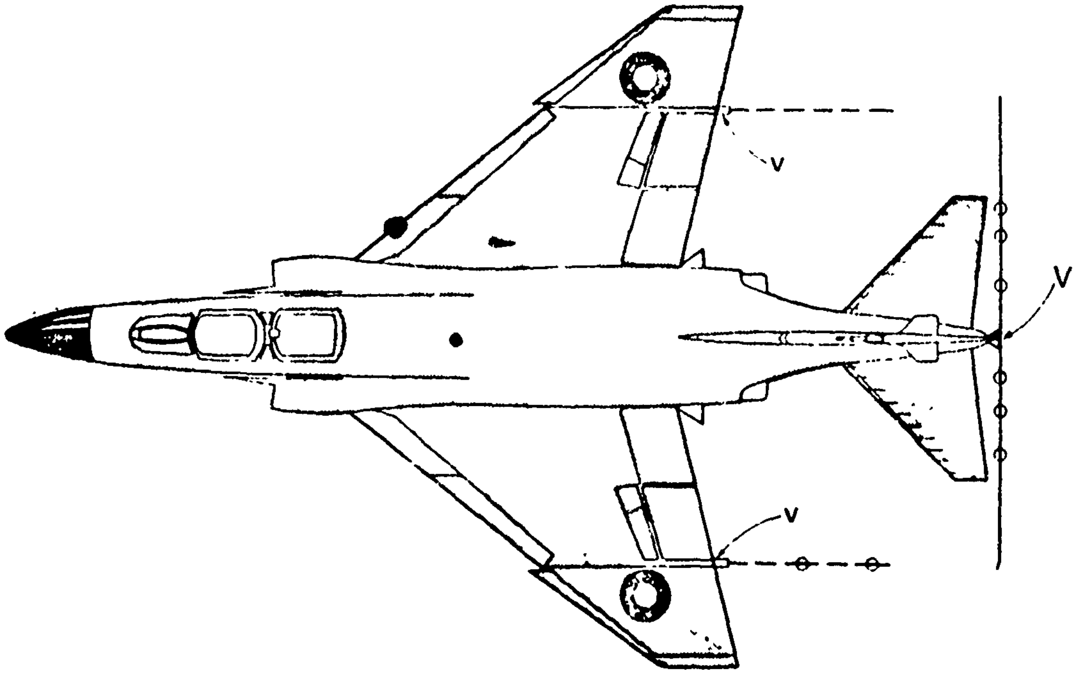
In comparing measurements accomplished during aircraft refueling inside the shelters with doors closed, the findings from the tropical areas should not apply in the central geographical areas such as Germany and the United Kingdom.

After completion of the proposed series of field tests by the NATO team a final safety report will be issued first quarter of 1981. Based on this report general engineering guidelines will be developed by the team for the NATO countries.

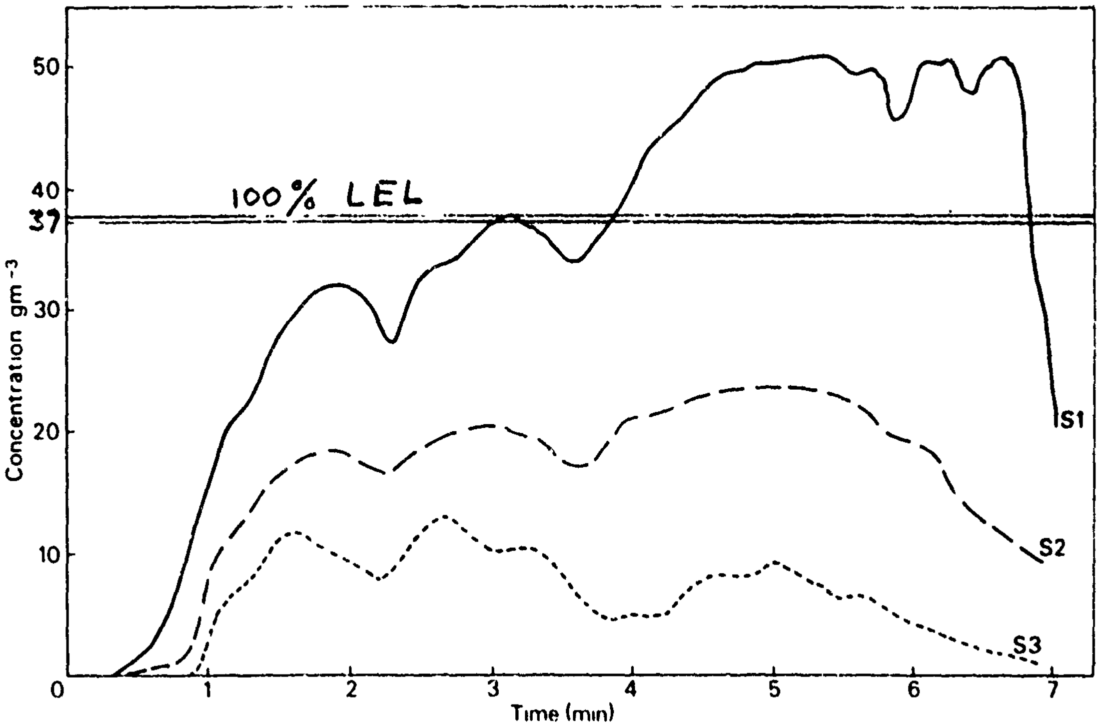
Three nations, United Kingdom, Norway, United States have already completed prototype facilities for in-shelter refueling of aircraft. The United Kingdom system primarily consists of a refueling truck parked in a hardened annex to the aircraft shelter.

The Norway system provides small satellite type storage tank with pumping and filtration unit either at each shelter or one system for a group of three shelters.

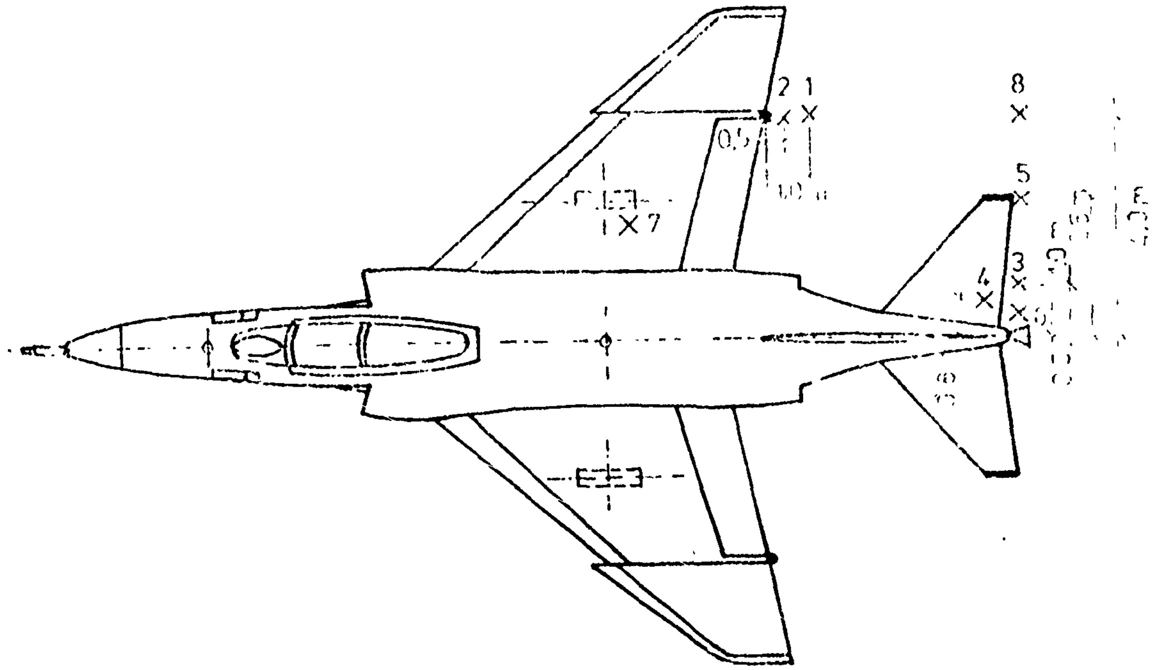
With the completion of the assigned task by the NATO In-Shelter Refueling Panel it is proposed to seek SHAPE approval of the refueling concept in order to eliminate a serious deficiency in survivability aspect.



Sketch of RAF Phantom indicating vents (V = main, v = wing)
axis of plume (— — —) and deployment of gas sensors (o)
Not to scale



Typical plume vapour concentration record phantom main vent with JP4 distance of sensors from vent
S1 0.75 m
S2 1.25 m
S3 2.0 m

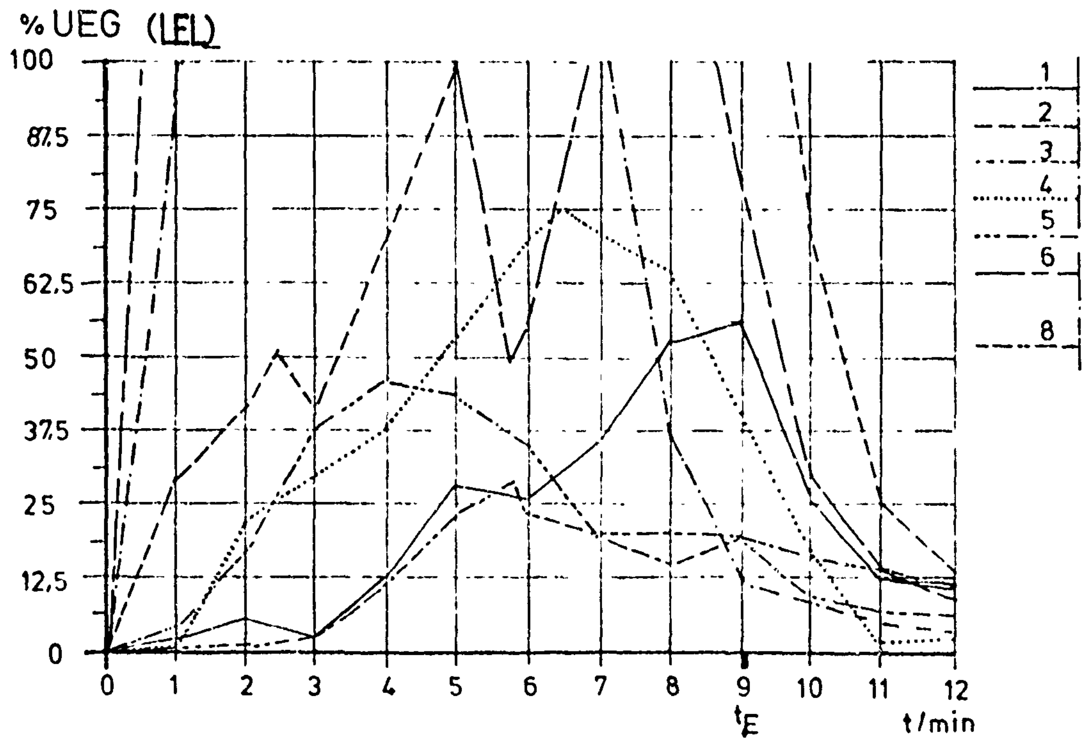


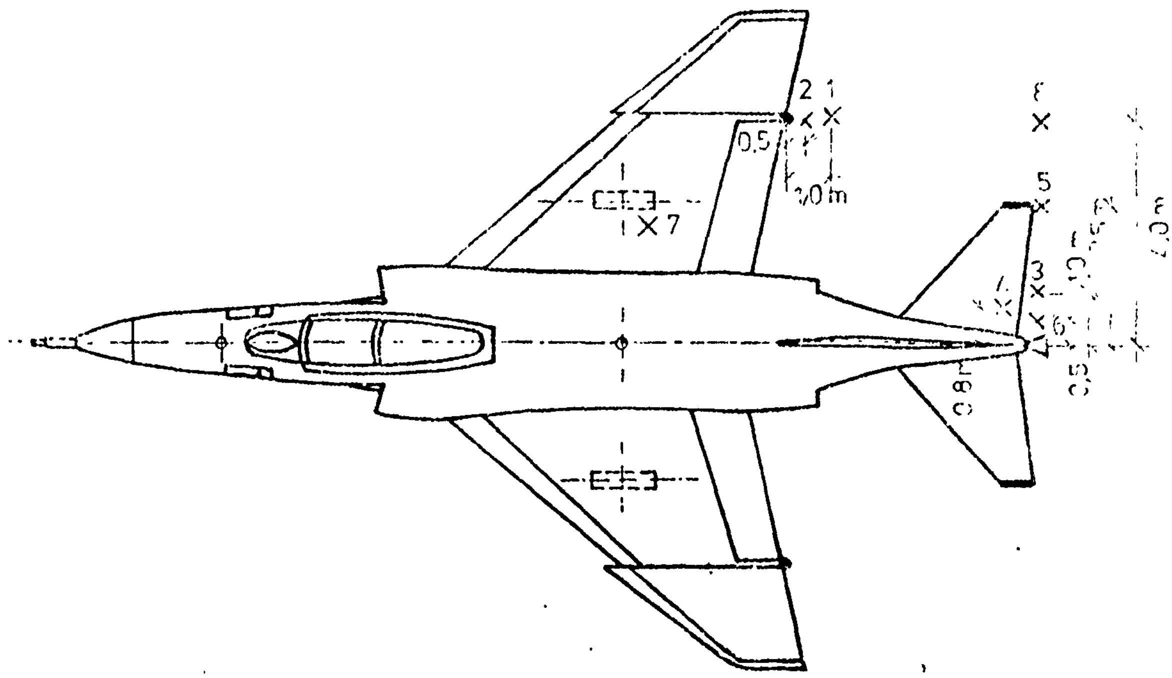
1.2 Sensors in center of fuel vapor mixtures

4 Sensor on horizontal-vertical stabilizator

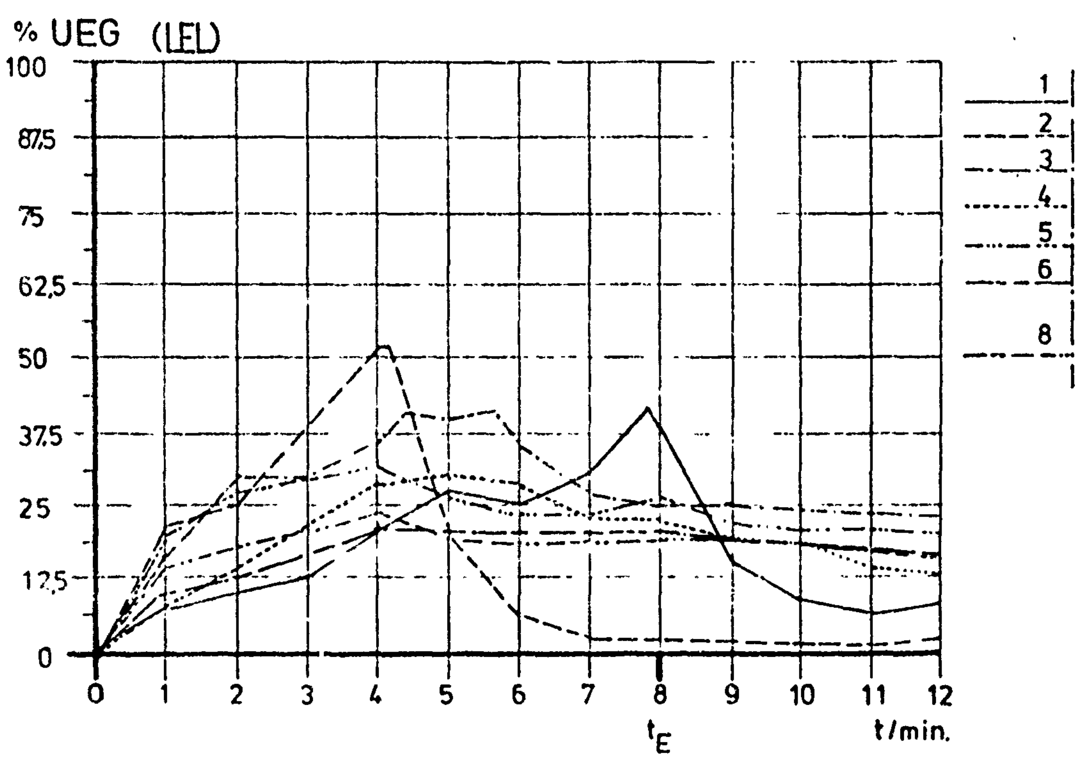
8 Sensor at floor level

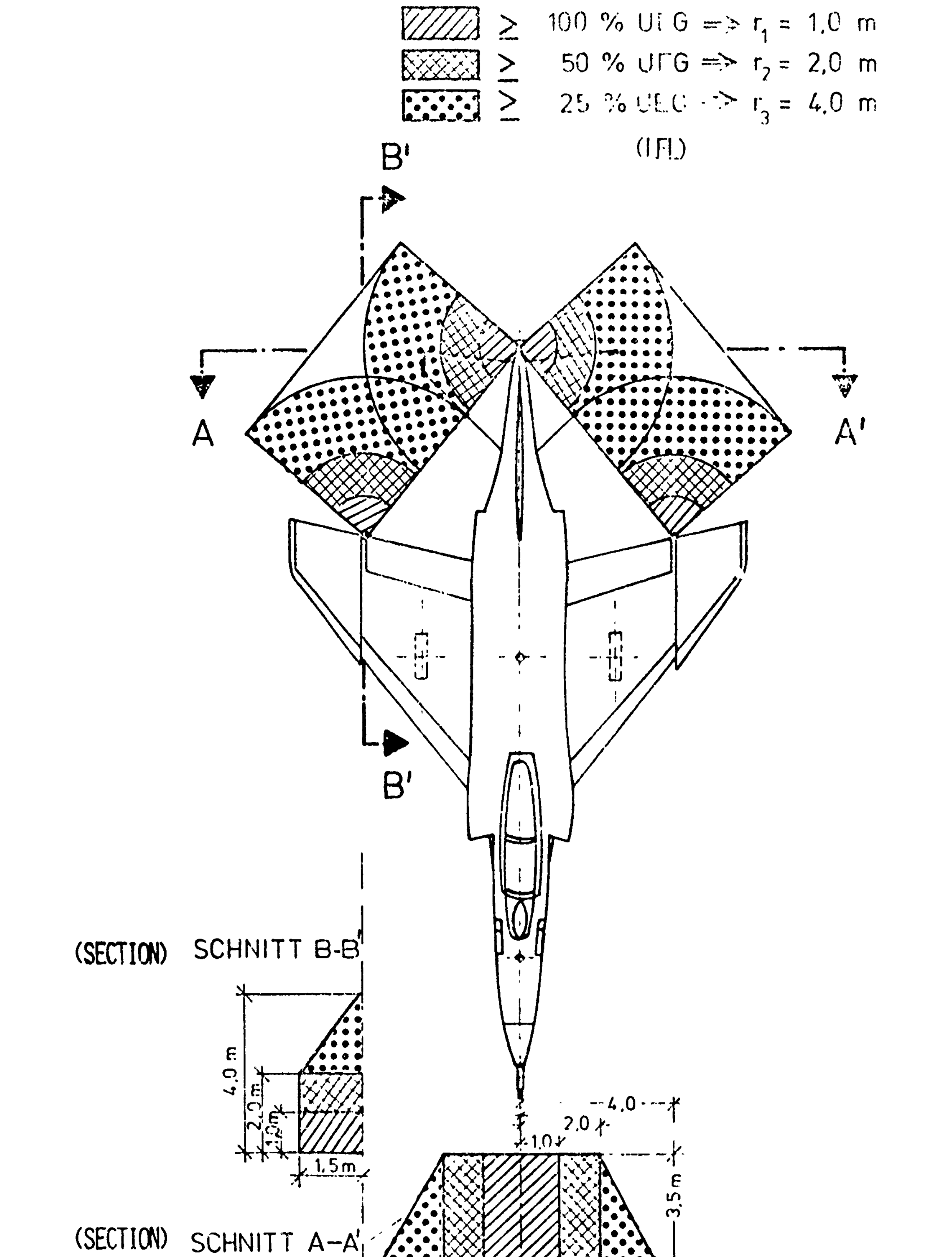
3.5.6 Sensors in center of fuel vapor mixtures





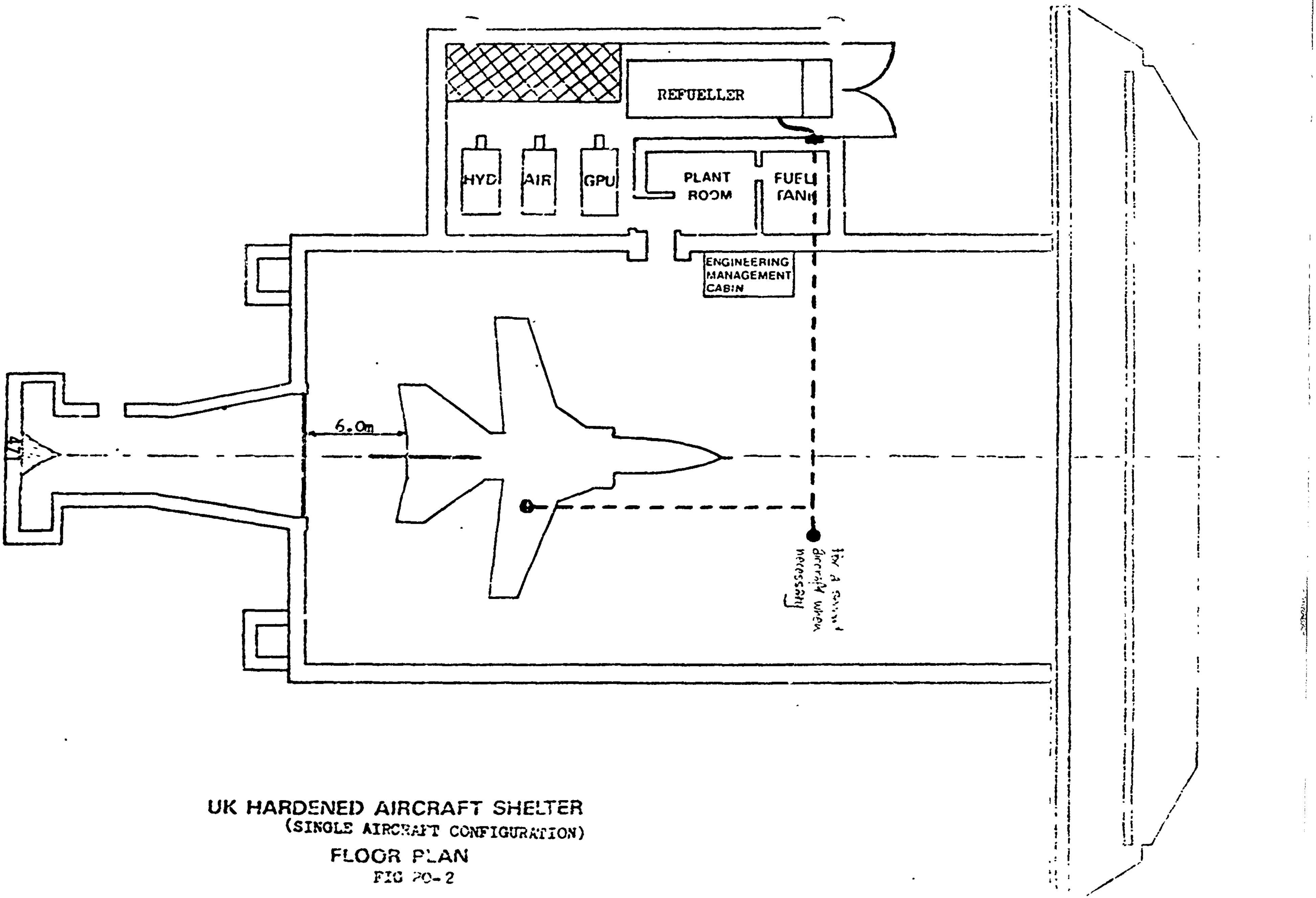
1,2	SENSORS IN CENTER OF FUEL VAPOR MIXTURES
3,58	SENSORS AT FLOOR LEVEL
2	H = 1,75 M
4	H = 0,40 M
6	H = 0,30 M





DANGER ZONES DURING REFUELING

F4 AIRCRAFT WITH JP-4



UK HARDENED AIRCRAFT SHELTER
(SINGLE AIRCRAFT CONFIGURATION)
FLOOR PLAN
FIG 20-2

AIRFIELD REFUELLING SYSTEM - SURVEILLANCE

Industry-Military Energy Symposium

San Antonio, Texas, USA

October, 1980

D. J. Keeling

BP Trading Limited

AIRFIELD REFUELLING SYSTEMS - SURVEILLANCE

The BP Group Aviation activity involves the manufacture, distribution and supply of approximately 5 % of the free world demand through 33 operating companies at over 800 airports, predominantly outside the Western hemisphere. The purpose of this paper is to provide an insight into the methods employed by Air BP, BP's International Fuelling Organisation, in maintaining operational standards throughout this network, including developments and problems in the area of cost effective surveillance.

Control/Co-ordination

The network requires significant control and co-ordination in the prime areas of any Aviation fuelling service; namely safety, serviceability and quality control. Effective safeguards must be built into the system to ensure that common universal standards are adopted both in facility design and operational practices. The method employed to regulate these standards depends very much upon a strong central authority, vested with the responsibility for quality assurance throughout all phases of distribution, and the management of a safe into-aircraft service at all airports within the Air BP Group. Comprehensive regulations are compiled governing all quality and operational aspects of the service and a surveillance mounted to ensure universal compliance with these requirements.

Standards

The concept of a universal standard dictates that aircraft fuelled from a sophisticated system in any advanced industrial environment should also receive comparable service at a third world fuelling stop.

Not always an easy proposition when faced with the frustrations of difficult supply systems and restrictions affecting the procurement of equipment or the placement of expatriate supervisory representation. A further complication in the universal application of a comprehensive standard is the incompatibility of some environmental or local authority influences which dictate waivers from the issuing body. Where this is justified appropriate dispensations are given. This provides a tighter control than the alternative of limited rudimentary regulations on which are superimposed additional local requirements.

These standards, together with the adoption of product specifications acceptable to all customers, form the basis of airline contractual commitments.

Such operating and quality control regulations are necessarily supplemented by engineering construction standards, proprietary equipment approvals and codes of safe practice etc.. Publications are continuously updated but where interim amendments are required, dictated by changes in equipment or operating practices, bulletins are issued calling for the mandatory adoption of the required modification. These bulletins in turn trigger the introduction of a local standing instruction from the operating company Head Office in the appropriate local language. Operating companies are therefore kept abreast of developments through the maintenance of an effective up-date service and the dissemination of this information throughout the network.

BP

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AIRBP INSPECTION ORGANISATION

AVIATION SALES, LONDON
CHIEF OPERATIONS ENGINEER-GROUP CHIEF INSPECTOR

- DEFINES QUALITY CONTROL PROCEDURES AND REQUIREMENTS IN AIR BP REGULATIONS
- SOLE AUTHORITY TO CLEAR OFF SPECIFICATION FUEL AND AVIATION PRODUCTS

ASSOCIATE COMPANY
CHIEF INSPECTOR

- RESPONSIBLE FOR
  - EFFECTIVE ORGANISATION ADMINISTRATION AND OPERATION OF INSPECTION ORGANISATIONS WITHIN –
    MANUFACTURING & PACKAGING PLANTS
    MAIN INSTALLATIONS
    SUB INSTALLATIONS
    AIRPORT INSTALLATIONS
  - NEGOTIATIONS WITH CONTROLLING AUTHORITIES AND CUSTOMERS CONCERNING QUALITY CONTROL REGULATIONS
  - ADVISING CHIEF OPERATIONS ENGINEER LONDON OF ALL QUALITY CONTROL MATTERS
  - RESPONSIBLE IN SOME MATTERS TO MILITARY/GOVERNMENT AUTHORITY

The name of the Chief Inspector, and position held must be advised to the Chief Operations Engineer Aviation Sales, London on the 1st January each year (Normally Aviation Manager or Aviation/Operations Engineer)

- DELEGATES RESPONSIBILITY TO

INSPECTORS

- RESPONSIBLE FOR
  - EFFECTIVE ARRANGEMENT OF THEIR INSPECTION ORGANISATION
  - CORRECT MAINTENANCE OF QUALITY CONTROL PROCEDURES
  - DOCUMENTATION OF OPERATIONS UNDER THEIR CONTROL
  - VERIFICATION AT TIME OF ISSUE THAT QUALITY IS SATISFACTORY

The appointment of Inspectors should be confirmed in writing. The Chief Inspector must maintain a register of names and position held in the Company (Normally Manager/Chief Chemist/Superintendent)

PRODUCT INSPECTORS

- RESPONSIBLE FOR
  - THE SATISFACTORY HANDLING OF PRODUCT FROM RECEIPT TO DELIVERY INTO AIRCRAFT IN ACCORDANCE WITH AIR BP REGULATIONS
  - ONLY PERSONNEL TRAINED IN THE REQUIREMENTS OF AVIATION PRODUCT HANDLING MAY BE DELEGATED WITH INSPECTION RESPONSIBILITIES. SUCH TRAINING MUST RELATE NOT ONLY TO PHYSICAL ACTIVITIES SUCH AS BLENDING INSPECTION MARKING & FILLING OF CONTAINERS ETC BUT ALSO COMPLETION OF THE DOCUMENTATION REQUIRED TO VERIFY THAT APPROVED PROCEDURES HAVE BEEN USED

Product Inspectors should be acquainted with their duties via written extracts from Air BP Regulations

Refineries	Manufact & Packaging Plants	Main & Sub Inst lns.	Airport Inst lns	Agencies
Laboratory Testing Tanker Barge R T C Bridger Loading Storage	Laboratory Testing Drum Filling Repackaging Blending etc	Tanker Barge etc Bridger Loading & Offloading Pipeline Discharge Storage.	Bridger Discharge, Pipeline Discharge. Fueller Loading Daily into Aircraft Storage	Bridger Discharge Fueller Loading. Daily into Aircraft Storage.

FOR FULL DETAILS REFER TO AIRBP REGULATIONS FUELLING & QUALITY CONTROL

AVIATION SALES BP TANK[illegible] LANE LONDON [illegible]

AIR BP Instruction Sheet No. 7 Issued June 1978

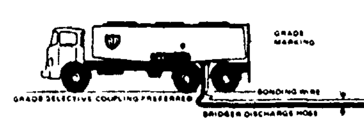
Inspectorate Structure

Having defined requirements, the imposition of a regular surveillance programme is necessary to ensure universal adherence to the common standard. Surveillance is not restricted to periodic inspections by Head Office personnel but is also achieved, in the quality assurance field, through the establishment of an integrated Inspectorate structure throughout the aviation product manufacture, storage and distribution phases. The Inspectorate comprises Product Inspectors undertaking the basic quality control tasks and forming the basis of the hierarchical structure . Inspectors are superimposed upon this base and fulfil the role of ensuring that Product Inspectors are fully acquainted with their function and carry it out correctly. Inspectors are normally the Chief Chemist at refinery laboratories or Depot Managers etc who carry authority for signing quality release documents. Chief Inspectors, head up the operating company structure and are responsible through surveillance of product, documents and procedures, for ensuring the effective execution of the quality control arrangement throughout the local network. These Inspectors are functionally responsible to the Group Chief Inspector at the Centre for all matters associated with aviation product quality. Thus there is an Inspection Hierarchy within the Group with a clear functional responsibility for adherence to regulation requirements from the individual, actually performing the function through to the authority writing the rules and controlling/co-ordinating the activity. Nominations from each operating company for the Local Inspector role are renewed annually and returned in writing to the Group Chief Inspector, a responsibility undertaken by the Chief Operations Engineer.

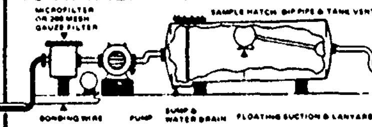
MINOR AIRFIELDS: AIR BP OPERATING & QUALITY CONTROL REQUIREMENTS

air BP

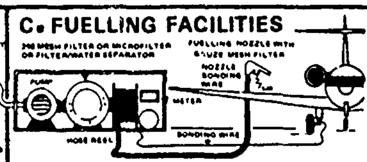
A. BRIDGER



B. AIRFIELD STORAGE



C. FUELLING FACILITIES



QUALITY CONTROL AND OPERATING PROCEDURES

All quality control procedures and checks to be carried out by the Product Inspector who will also maintain relevant records

A. Bridger

1 ALL BRIDGER CONSIGNMENTS must be accompanied by a release note providing the following information –
- 1 1 Grade and quantity
- 1 2 Specification
- 1 3 Batch No
- 1 4 Date
- 1 5 S G at Standard Temperature
- 1 6 Certification that product is free from dirt and water
- 1 7 Signature of authorised Product Inspector

2 ON ARRIVAL of bridger the following checks must be made before discharge –
- 2 1 Information on Release Note
- 2 2 All seals are intact
- 2 3 Correct grade marking displayed for the product ordered
- 2 4 Allow 10 minutes settling time
- 2 5 Break seals Drain product from all vehicle compartments until free from water and dirt Draw sample from each compartment for Visual Tests and Density and Temperature determination for comparison with the figure quoted on the release note (If difference greater than 003 after correction to standard temperature consignment must be rejected)
- 2 6 All checks together with date and time of discharge must be recorded on the release note which should be signed and retained at the airfield When bridger is not dedicated or fitted with selective couplings checks must be verified by a second man and the release note signed accordingly

3 BRIDGER DISCHARGE procedure
- 3 1 Compare grade marking on bridger with that on tank
- 3 2 Product must not be discharged unless the Product Inspector is present to receive it
- 3 3 Dip storage tank to ensure adequate ullage is available
- 3 4 Connect bonding wire to bridger
- 3 5 Connect discharge hose
- 3 6 Off load product

4 ON COMPLETION OF DISCHARGE
- 4 1 Disconnect hose
- 4 2 Disconnect bonding wire
- 4 3 Dip tank to verify correct transfer of product

B. Airfield Storage

1 SETTLING After replenishment the following settling time must be observed before product may be released –

1 1 Where delivery into storage is through a microfilter or filter/water separator	1 hour total
1 2 Where delivery into storage is through a gauze mesh filter	1 hour per foot of product

2 TANKS must be kept free from dirt and water by drawing samples from the water drain until a satisfactory Visual Test is obtained at the following frequency
- 2 1 After every replenishment on completion of settling
- 2 2 Daily at the start of operations
- 2 3 After torrential rain thawing snow or flood
- 2 4 Prior to an aircraft fuelling at points manned intermittently
- 2 5 All the above checks must be recorded on the Dirt and Water Precautions Certificate

3 Every six months draw a one litre sample for Short Testing (Aviation Gasoline only)

4 200 Mesh Gauze Filter or Microfilter or Filter/Water Separator
- 4 1 Every day draw a sample of product from the sump drain point until a clear sample is obtained (Record in the Dirt and Water Precautions Certificate)

C. Fuelling Facilities

1 FUELLING THE AIRCRAFT Overwing –
- 1 1 Always be sure that the grade to be delivered is correct for the particular aircraft If the grade is not clearly marked on the Aircraft fuelling must not commence until clear instructions are received from the pilot If there is a language difficulty use the Fuels Identification Chart
- 1 2 Bond the aircraft to the fuelling facility
- 1 3 Run out delivery hose (be careful to avoid kinking) connect nozzle bonding wire to the aircraft before removing the tank filler cap The nozzle must be placed in contact with the wing before the cap is opened
- 1 4 On completion of delivery withdraw nozzle replace tank cap before disconnecting bonding wire rewind hose
- 1 5 Disconnect and reel in main bonding wire

2 PRECAUTIONS –
- 2 1 Fuelling operations must always be carried out by competent trained personnel
- 2 2 Hoses must be routed on to the wing in such a manner that no possible damage can be incurred
- 2 3 Hoses must never be routed over the wing trailing edge
- 2 4 Care must be exercised to prevent damage to the wing surface by the nozzle The spout must be small enough to enter the filler neck of the tank, and leave sufficient space for displaced air to escape
- 2 5 Hose trigger nozzles should be held open manually and never wedged open The weight of the nozzle should be supported at all times
- 2 6 Care must be taken to avoid dropping articles into the tank
- 2 7 Fuelling is not permitted –
  - 2 7 1 In hangers or other confined spaces
  - 2 7 2 During electric storms dust storms or excessively heavy rain

Visual Test and Sampling Procedure

1 A four litre sample must be drawn at full flush into scrupulously clean clear glass jar

2 To be acceptable fuel shall be the correct colour visually clear bright free from solid matter and undissolved water at normal ambient temperature
- 2 1 Colour The various grades of Aviation Gasoline are dyed to aid recognition while the Colour of Aviation Turbine Fuels may vary from water white to straw colour
- 2 2 Undissolved Water Will appear either as droplets on the sides or bulk water on the bottom of the sample jar It will also appear as a cloud or haze
- 2 3 Solid Matter Will generally consist of small amounts of rust sand dust or scale etc suspended in the fuel or settled out on the bottom of the jar
- 2 4 Clear Refers to the absence of sediment or emulsion Bright refers to the sparkling appearance of the fuel having no cloud or haze

3 When carrying out tests for Solid Matter swirl the sample to form a Vortex thereby causing any dirt present to concentrate at the centre of the vortex making it more readily visible

4 Testing for Free and Suspended water must be carried out as follows
- 4 1 Drop two or three potassium Dichromate tablets into the sample any water present will become coloured which will make it readily visible
- 4 2 Carry out syringe and capsule water detector test (Jet A 1 only) –
  - 4 2 1 Check that the capsule shelf life as marked on the base of the container is not exceeded Fit capsule to the syringe and immediately withdraw a 5 ml fuel sample
  - 4 2 2 Examine the capsule for any colour change between the inner wetted area and the outer annulus If there is a distinct colour change product must not be issued
  - 4 2 3 Capsules may only be used once

FUEL MUST NOT BE DISCHARGED FROM BRIDGERS OR RELEASED FROM STORAGE UNLESS THE VISUAL TEST IS SATISFACTORY

MAINTENANCE

B. Airfield Storage

6 HOSES
- 6 1 Monthly visually examine for deterioration and replace as necessary

7 STORAGE TANK
- 7 1 Monthly Check the buoyancy of floating suction

8 GAUZE MESH FILTERS OR MICROFILTERS OR FILTER/WATER SEPARATORS
- 8 1 200 Gauze Mesh Filters Weekly – inspect and clean replace when necessary
- 8 2 Microfilter or Filter/Water Separator Weekly observe and record the pressure differential Change the elements when pressure differential reaches that stated on the unit
  Yearly Open inspect and clean, replace elements if necessary
  (To be carried out by specialist personnel)

9 GRADE SIGNS
- 9 1 Ensure that the correct grade signs are prominently displayed on all tanks, fuelling connections and outlets

10 BONDING REEL AND CABLE
- 10 1 Weekly Check electrical continuity

C. Fuelling Facilities

3 HOSES
- 3 1 Monthly Visually check while under fuelling pump pressure

4 DELIVERY NOZZLE
- 4 1 Weekly
  - 4 1 1 Check bonding wire and clip replace if necessary
  - 4 1 2 Check and replace weather protection cap as necessary
- 4 2 Monthly
  - 4 2 1 Remove strainer clean and replace if necessary

Grade selective couplings preferred on all bridging vehicles and bridger discharge facilities

DOCUMENTATION

QUALITY CONTROL
1 Release Note (covering bridger supplies)
2 Dirt and Water Precautions Certificate (Visual Tests on tanks and filters)
3 Stock Record
4 Filter/Water Separator Pressure Drop Record
5 Short Test Certificate (Six monthly on storage tanks – Aviation Gasoline only)

MAINTENANCE
1 All maintenance checks to be recorded in a suitable log book

SAFETY

1 NO SMOKING signs must always be displayed in the vicinity of fuelling equipment or operations [illegible] No Smoking Area
2 Fire extinguishers must always be readily available
3 The telephone number of the fire service must be prominently displayed
4 Vegetation which could become a potential fire hazard must be kept short
5 Metal containers used for fuel sampling and draining must be bonded [illegible]

NOTE FOR FURTHER DETAILS REFER TO AIR BP REGULATIONS FUELLING AND QUALITY CONTROL

AVIATION SALES DIVISION BRITANNIC HOUSE MOOR LANE LONDON EC2Y 9BU
[illegible] BP [illegible] Sheet No [illegible] Issued March 1976
BP Printing England 4/76

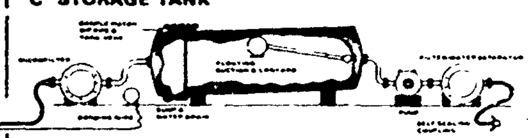
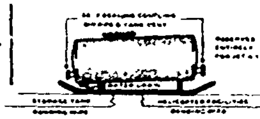
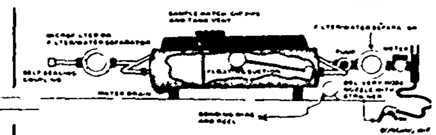
Inspection

Having produced the regulations, established the standard and set up the Inspectorate structure, the organisation is then policed on a periodic basis, using a check list derived from the latest regulation requirements. The inspection process involves a step by step surveillance of aviation distribution systems, major airfield facilities and a representative number of minor points, including offshore helicopter fuelling facilities etc. At airfields, selected quality defences are dismantled and functional tests carried out on equipment such as pressure control valves etc. A further important feature of the inspection is a detailed examination of quality control and serviceability documentation. The frequency of inspection ranges from a few months in the more vulnerable areas, to 1 ½ years where records demonstrate traditionally high standards. On average, every operating company is inspected at a frequency of 12 months.

Staffing

Such surveillance arrangements involve a relatively heavy programme which imposes considerable demands on inspection staff. Inspectors are periodically rostered to different operating companies such that a change of approach and a new emphasis of expertise is brought to bear. It also increases the knowledge spread of network systems at the Centre. We have also recently supplemented the central team with senior engineers within the Inspectorate, but employed by the operating companies. This has proved successful, particularly where follow-up action in a third world country is concerned and a common language exists and/or former colonial trading links have been maintained.

air BP

ACILITIES	A REFINERY MARKETING TANKAGE	SUB-INSTALLATION: B BRIDGER	SUB-INSTALLATION: C STORAGE TANK	SUB-INSTALLATION: D TRANSIT TANK	E HELICOPTER FUELLING FACILITIES
					
ALITY CONTROL & OPERATING PROCEDURES [illegible]	1 Jet A-1 manufactured to meet the relevant specification 2 All bridger consignments must be released under cover of a Release Note providing the following information 1.1 Grade 1.2 Quantity 1.3 Batch Number 1.4 Date 1.5 S.G. at Standard Temperature 1.6 Certifies free of Dirt and Water 1.7 Signed by Author and Product Inspector 1.8 All manholes, lid and outlet connections must be sealed 1.9 Grade Plate displayed [illegible]	1 Release Note must accompany bridger	1 [illegible] 2 [illegible] 3 [illegible] 4 [illegible]	[illegible]	1 Product Reception and Storage 1.1 Carry out all Quality Control checks and procedures, see column C items 1 to 4 (S.G. and Temperature not required) 2 Fuelling Procedure 2.1 Fuelling must not begin until passengers have disembarked and are clear of the [illegible] and engines are stopped [illegible] 2.2 [illegible] 2.3 Start pump. Draw sample from delivery nozzle. Carry out Visual Test. [illegible] 2.4 [illegible] 2.5 [illegible] 2.6 [illegible] 2.7 [illegible] 2.8 Draw sample from FILTER/WATER SEPARATOR [illegible] VISUAL TEST [illegible] VISUAL TEST [illegible] 2.9 [illegible]
		VISUAL TEST AND SAMPLING PROCEDURE 1 [illegible] 2 [illegible] 3 [illegible] 4 [illegible] 5 FUEL MUST NOT BE [illegible] UNLESS THE VISUAL TEST IS SATISFACTORY			
MAINTENANCE REQUIREMENTS			5 [illegible] 6 [illegible] 7 [illegible] 8 [illegible] 9 [illegible]		3 Transit Tanks Carry out maintenance in accordance with column C items 7.2 and 8 4 Fixed Facilities Carry out maintenance in accordance with column C items 5, 6, 7 and 8 5 Delivery Hose 5.1 [illegible] 5.2 Every Two Years: Replace 6 Delivery Nozzle 6.1 [illegible] 6.2 Monthly: Check bonding wire and clip. Replace if defective 6.3 Monthly: Check and renew weather protection caps as necessary
RECORDS			10 Quality Control Records 10.1 [illegible] 10.2 [illegible] 10.3 [illegible] 10.4 [illegible] 10.5 [illegible] 11 Maintenance Records 11.1 Weekly and Monthly Serviceability Report		7 Quality Control Records See column C items 10.1, 10.3, 10.4 and 10.5 8 Maintenance Records Weekly and Monthly Serviceability Report

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NOTE: FOR FURTHER DETAILS REFER TO AIRBP REGULATIONS - FUELLING & QUALITY CONTROL

HELICOPTER FUELLING, QUALITY CONTROL AND OPERATING PROCEDURES

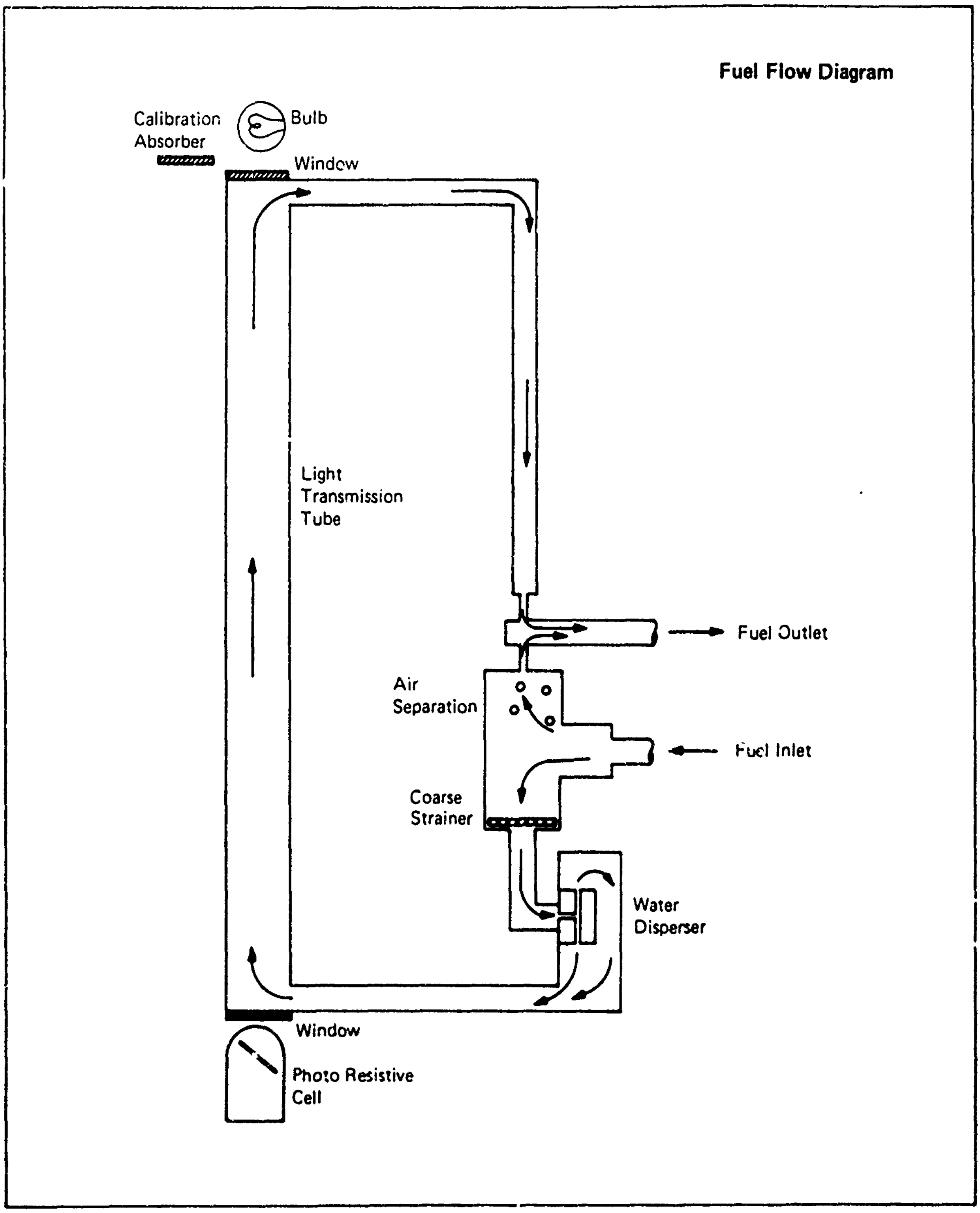
Air BP
Instruction Sheet No. 2
Issued
November 1975
(Amended April 1980)

Turning to the central team, BP does not believe in the use of the 100 % Inspector. Experience has shown that staff who are continually travelling become less than effective due to the relative tedium of the process. In addition it can also have an adverse effect on family and social life, ultimately leading to a less balanced individual. There is also a real danger that the Inspector will lose touch with the main stream of aviation development, both in equipment and practices etc. This function therefore devolves upon experienced Operations Engineers with an extensive field service, who handle the day-to-day requirements of the operating companies, provide representation on international aviation bodies and generally undertake the technical liaison necessary within an integrated oil company.

Joint Systems

A number of international forums have been developed to increase the effectiveness of the surveillance process at facilities operated in partnership with other suppliers, and BP has been an active industry voice in these developments. With the movement in recent years towards large joint airfield fuelling systems it became readily apparent that a number of ill-timed unco-ordinated surveillance commitments by all participants, with varying requirements, could ultimately be counter-productive. An Industry Group Inspection scheme was therefore set up under BP's co-ordination to organise a comprehensive annual inspection programme, providing one Inspector from each participant, rotated annually, with the designated Inspector receiving the full support of all concerned. A system of periodic review and follow-up has also been built into the scheme, providing support from all participants where remedial action is necessary.

air BP Fuel Monitor



Monitor Aids

Quality control procedures currently in force have proved satisfactory over many years in ensuring the delivery of on-specification clean, dry fuels to aircraft. They are based on the visual examination of fuel samples drawn by trained operators from a number of carefully selected points in the fuel system and facilities are designed such that any water which may be present can be readily detected and drained off. Floating suction offtakes in storage tanks, internal lining of tanks and pipelines and the installation of microfilters and filter/water separators are features of system design which provide further quality assurance. The development of reliable and practical instruments/monitors further reinforce system integrity, by eliminating the possibility of human error, which together with economies resulting from reduced manual effort, are natural objectives currently being pursued.

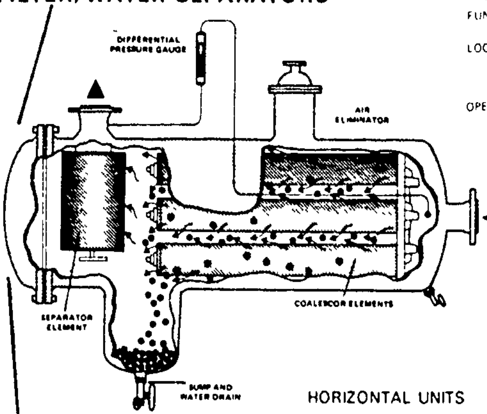
An Air BP fuel monitor has been developed which provides for the continuous electronic surveillance of water free product down to levels of less than 5 ppm, a number of these units have been deployed throughout the network in static and mobile equipment to provide an indication of free water levels and to confirm the reliability of the instrument. One unit equipped with a chart recorder is currently in use monitoring participant supplies into a major European jointly operated hydrant system. This gives a permanent record of incoming quality and provides a ready reference in the event of local quality problems associated with any Participant fuel supply prior to co-mingling. Use of this monitor is also particularly appropriate in areas where filter/water separator performance cannot

BP

FILTRATION/WATER SEPARATION

air BP

FILTER/WATER SEPARATORS



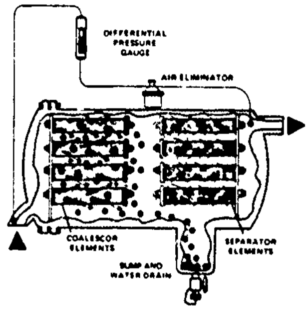
HORIZONTAL UNITS

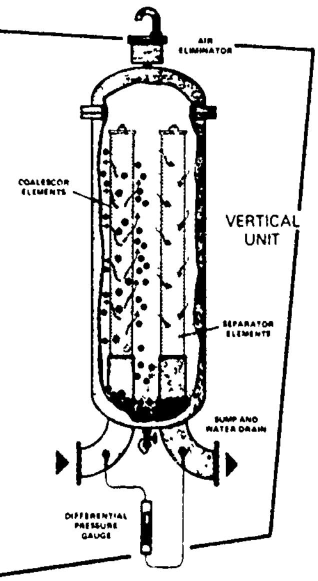
FUNCTION To remove any dirt down to 5 micron and water down to 15 p.p.m. which may be entrained in the fuel

LOCATION Airport Installations – Upstream of storage
Fueller loading points
Entry to hydrant mains
Mobile Jet A 1 Fueller and Dispenser Units

OPERATION Product flows into the vessel through the coalescor elements where entrained solids are trapped.

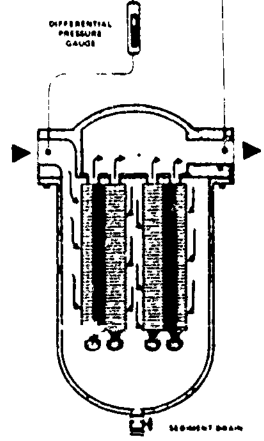
Any water present is coalesced into large droplets most of which fall under gravity into the sump. Any fine water droplets carried over pass to the separator element where further coalescence takes place, large droplets are again formed which gravitate to the sump.





* PRESSURE DIFFERENTIAL READINGS MUST BE RECORDED WEEKLY AT THE SAME FLOWRATE AS FLUCTUATING FLOWRATES WILL PRODUCE INCONSISTENT RESULT
* SUMPS SHOULD BE DRAINED DAILY [illegible] IN ADDITION ON HYDRANT DISPENSERS IMMEDIATELY FOLLOWING [illegible]
* ELEMENTS MUST BE CHANGED IF ANY OF THE FOLLOWING CONDITIONS OCCUR [illegible] RECOMMENDED MAXIMUM [illegible] TEFLON COATED SEPARATOR ELEMENTS MAY CONTINUE IN SERVICE PROVIDING THEY SATISFY THE APPROPRIATE TEST REQUIREMENTS NOTE: TIME LIMIT DO NOT APPLY TO MICROFILTER [illegible] CONTAMINANTS
* INTERNAL INSPECTION MUST BE CARRIED OUT YEARLY AS FOLLOWS [illegible] CONTAMINATED OR FAILS DEFECTIVE THEY MUST BE REPLACED [illegible]
* [illegible]

MICROFILTERS

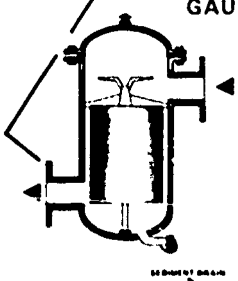


FUNCTION [illegible]

LOCATION [illegible] Upstream [illegible] AVGAS [illegible]

OPERATION [illegible]

GAUZE FILTER

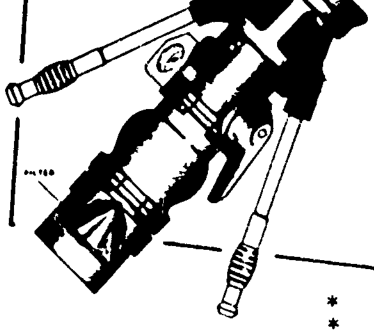


FUNCTION [illegible]

LOCATION [illegible]

OPERATION [illegible]

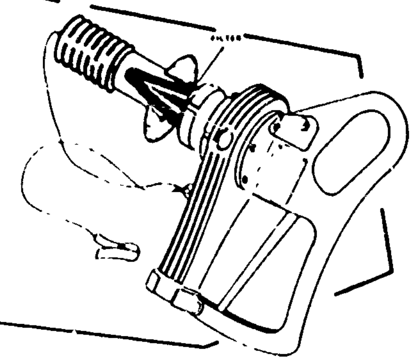
HOSE END FILTERS



FUNCTION [illegible]

LOCATION [illegible]

OPERATION [illegible]



FOR FULL DETAILS REFER TO AIRBP REGULATIONS FUELLING AND QUALITY CONTROL

be relied upon because of possible surface active agent (surfactant) contamination.

Quality Defences

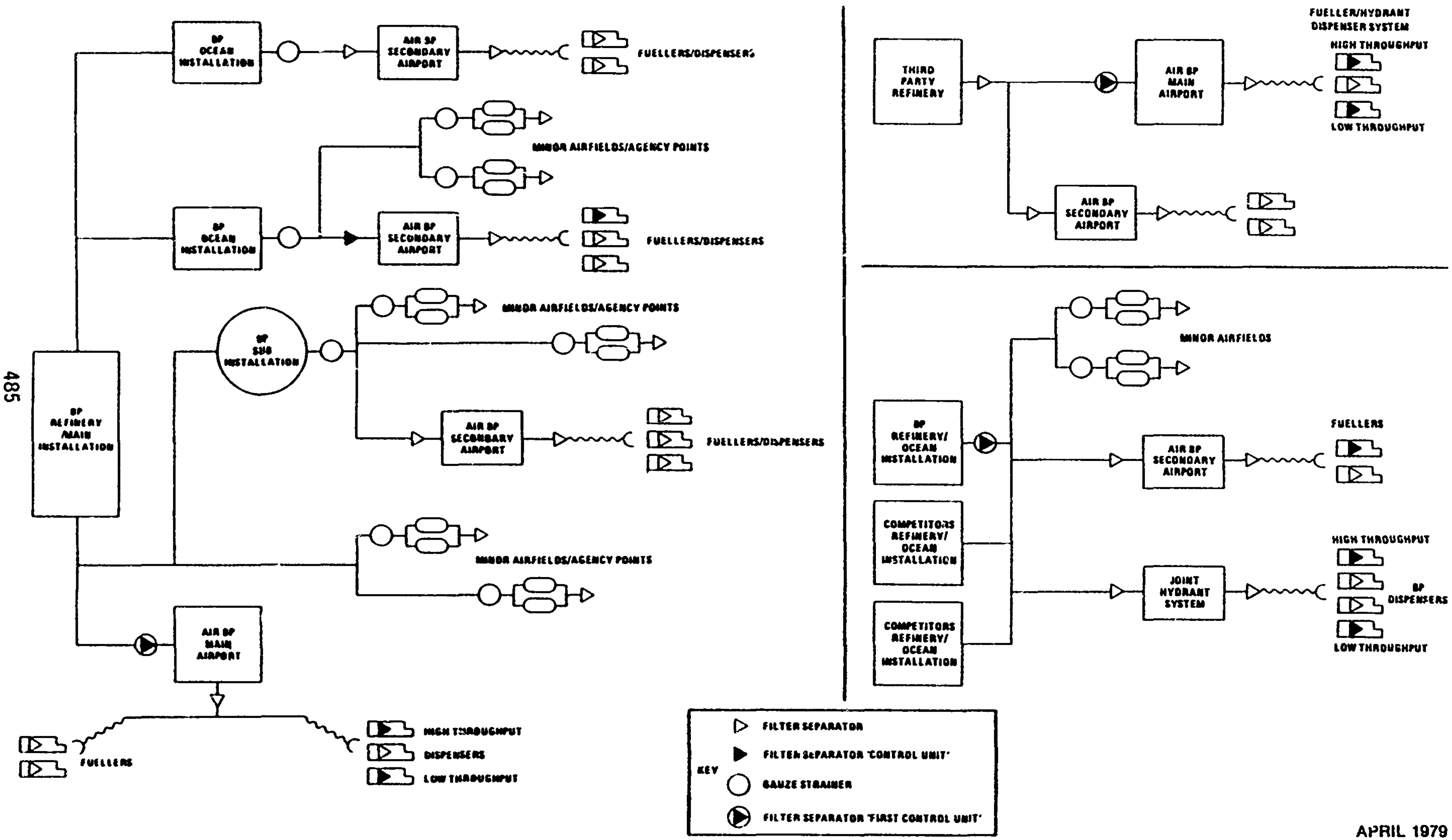
Surfactant disarming of quality defences has led to the adoption of single element testing equipment throughout the network and the regulation of filter/water separator life by performance assessment in place of an arbitrary life limitation. Operating companies are encouraged to install their own visi-rig equipment where possible, rather than forward elements to our central test establishment. On-site testing has a number of advantages, both economic and functional, but in addition it engenders a local awareness of the surfactant problem and provides a ready demonstration of effective coalescence.

Using this system, savings in element replacement are realised where satisfactory performance permits life extension. More importantly, testing can identify the presence of surfactants in unsatisfactory fuel sources. Control is exercised by nominating a filter/water separator at a strategic point in the fuel delivery system, such that it will be exposed to a significant proportion of product from sources feeding a particular area of the network. These control units are selected to give coverage to virtually all downstream Aviation activities and provide a quality assurance measure against surfactant contamination of the system. Elements are extracted annually or at every pressure differential change, limited to a maximum frequency of 3-4 times a year. Failure of a control element triggers upstream investigations and further testing to assess the status of downstream units. In addition representative downstream elements are

Appendix No. QC. 14

air BP | COALESCOR PERFORMANCE CONTROL SCHEME

* LARGE AREAS MAY COMPRISE TWO OR MORE INDIVIDUAL SYSTEMS



APRIL 1979

tested annually to provide a basis for filter/water separator life extension, chiefly on apron equipment.

Hydrant Integrity

Recent discoveries of hydrant line leakage in certain European systems has led to reconsideration of construction standards. Current hydrant system practice with respect to buried lines in the areas in which BP operate, is the Epoxy lining of internal surfaces, conventional coaltar enamel external coating with fibre galss and asbestos wrapping, and cathodic protection. Where these practices are employed there is firm ground for expecting satisfactory leak free operations for very extended periods of time. However not all systems are in such a condition; the first major airport hydrants with which BP were associated are approximately 20 years old and occasional leakage problems are being encountered at some of these older systems.

Past design practices in terms of leak detection have been inadequate; ultrasonic methods are not easily employed in a noisy airport environment and static pressure testing can lead to a virtual disruption of services. Future hydrant design should therefore accommodate built-in equipment capable of identifying the presence and location of fuel leakage and we are currently considering the adoption of the following design standards: -

1. That systems be sectionalised for static pressure testing purposes. Each section to be terminated by double block and bleed valves and to incorporate, within a standard hydrant pit, means for test pressure application and fuel temperature measurement probes.

2. That the number of sections be such that 75 % of the aircraft fuelling stands can be maintained in full operation throughout any part of the testing procedure even if this necessitates the duplication of certain lines.

Such arrangements would enable the execution of meaningful routine pressure testing and verification of system integrity through the periodic surveillance process.

Surveillance Value

Having presented the case for controlling an organisation by surveillance it is useful to reflect on the consequences of failure in such a system. It is perhaps self evident that because an international inspection has taken place and a clean bill of health received, it does not automatically follow that there is unlikely to be any problem in the ensuing 12 months. The system requires day-to-day vigilance on the part of all members of the Inspectorate structure. There is no magic formula for a safe service and it largely depends upon individuals setting high standards for themselves and the staff subordinate to them.

Perhaps the most dangerous aspect of the Aviation fuelling activity is complacency. Regular inspection is of prime importance to confirm compliance with the standards written for the system and the maintainence of satisfactory equipment serviceability. It should keep field personnel on their toes and minimise the possibility of slackness. The best operations reflect the competence of individuals in the Inspectorate and the frequency of the inspection process. Regular surveillance visits also provide the opportunity for

on-the-job training and these functions can be inter-related processes; such visits provide enthusiastic field staff with the opportunity to demonstrate their keenness and ability and promote the close communication links essential for the motivation of all concerned.

The provision of a fuelling service based on more than 50 years of experience, operating under the balanced influences of commercial enterprise and integrated insurance cover, has enabled BP to develop a cost effective, safe operation. The continuous interchange of operational experience and ideas between the operating companies, co-ordinated by the Centre, also improves overall expertise and ensures optimum solutions to current and future needs.

RICHARD T. HEADRICK - CONSULTANT

GLOBAL MARINE DEVELOPMENT CORP

PRESENTED A FILM ON OIL SPILL CLEANUP

THE NARRATIVE WAS UNAVAILABLE

PRESENTED TO THE

INDUSTRY-MILITARY ENERGY SYMPOSIUM

21 - 23 OCTOBER 1981

SAN ANTONIO, TEXAS

Report No. FAA-CT-81-156

AIRCRAFT FIRE SAFETY RESEARCH WITH ANTIMISTING FUELS

Eugene Klueg

PRESENTATION

OCTOBER 1980

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City Airport, N.J. 08405

AIRCRAFT FIRE SAFETY RESEARCH

WITH ANTIMISTING FUELS

EUGENE P. KLUEG

FEDERAL AVIATION ADMINISTRATION

TECHNICAL CENTER

PRESENTATION AT THE INDUSTRY-MILITARY ENERGY SYMPOSIUM,

OCTOBER 22, 1980/SAN ANTONIO, TEXAS

1. INTRODUCTION/BACKGROUND.

The survivability of aircraft occupants in jet transport crashes can be significantly enhanced by minimizing post-crash fire hazards. One of the greatest dangers is the fireball resulting from ignition of spilled fuel during the crash deceleration. Frequently, in an impact survivable crash, fuel tanks rupture and large amounts of fuel are released while the aircraft is still in motion. Under these conditions, fuel sheared by the airstream forms a highly flammable mist which is easily ignited by engine surges, hot engine components, electrical or frictional sparks generated during the aircraft breakup, or other crash related ignition sources. These mist ignitions are explosive, and typically, the fire propagates to the fuel release locations, flames become attached to the aircraft and ignite fuel in and pooled around the damaged aircraft as it comes to a rest. In such crashes, approximately 30 percent of the fatalities are a direct result of fire or the resulting heat, smoke, and toxic gases. Thus, impact survivable aircraft crash landings become major disasters as a result of the fire fatalities and property losses.

Research efforts were initiated in 1964 by the Federal Aviation Administration (FAA) to develop a modified fuel which could be used in routine flight operations and also be capable of reducing the fire hazard during survivable crash by:

a. Restricting spillage from ruptured tanks
b. Decreasing the probability of ignition
c. Reducing flame propagation rates, and
d. Eliminating the mist of combustible vapors

This research produced the highly viscous gelled fuels of the late 1960's and early 1970's. Although the fire reduction characteristics of these fuels were good, the engine and aircraft fuel system and ground refueling system compatibilty problems were severe. Early in 1972, new antimisting fuels were developed consisting of 0.2 to 0.5 percent high molecular-weight polymeric additives with viscosities approaching those of conventional fuel. Testing indicated that the fire suppression characteristics of these antimisting fuels were comparable to the earlier viscous gelled fuels.

However, as a result of a failure of an antimisting fuel during a crash test in 1973, the FAA program was dramatically reduced. The effort from 1974 to 1978 was

directed toward developing a better understanding of the fuel break-up and ignition/flame propagation mechanisms in crash environments. This includes the development of a prototype wing spillage test to simulate the aircraft crash environment.

Public hearings by the FAA on Fuel Systems and Cabin Fire Safety in 1977, prompted the FAA to reexamine the status of Antimisting Fuel Technology. Results of ongoing research efforts in the United States (U.S.) as well as in the United Kingdom (U.K.) where the bulk of work was being done, were encouraging. This, together with the high loss in life in the Canary Islands accident, resulted in the FAA Antimisting Program being greatly expanded in 1978. The program was expanded under a Memorandum of Understanding (MOU) between the United States and the United Kingdom to cooperate in determining the feasibility of introducing Antimisting Fuel into civil aviation, using a British developed additive. The principal participants under the MOU were the FAA and the Royal Aircraft Establishment (RAE) of the United Kingdom, with the National Aeronautics and Space Administration (NASA) as a third party to undertake basic research and to provide technological support. The British developed additive is manufactured by Imperial Chemical Industries (ICI) ((ICI) Americas and ICI Limited), and is a high molecular-weight hydrocarbon polymer termed FM-9. This proprietary additive is dissolved in Jet A using a glycol/amine carrier fluid.

2. FAA ANTIMISTING FUEL PROGRAM.

In conjunction with the MOU, the FAA developed a phased program to direct research and development efforts to accomplish the following:

a. Determine the feasibility of using antimisting fuel.
b. Develop recommendations as to the introduction and use of antimisting fuel in civil aviation operations.
c. Demonstrate the effectiveness of antimisting fuel in a crash.
d. Assess the economic reasonableness in support of regular actions.

The basic program utilizes the FM-9 Jet A fuel with a carrier fluid, as a representative agent to prove the concept of using such fuels. Parallel to this main effort are investigations to identify other potentially acceptable fuels. The overall schedule of this FAA program is shown in figure 1.

The feasibility/FM-9 development, Phase I, is a 4-year effort designed to determine the feasibility of using such fuels, and the scope of effort required to produce a successful fuel, should the feasibility be established. The acceptability of this fuel is being examined through the establishment of the basic characteristics and by subjecting the fuel to large-scale tests (figure 2).

This includes identification of major problem areas associated with the use in airport, aircraft, and engine systems. Production, quality control, and cost are also being examined under this phase.

The FAA is concentrating the feasibility efforts on FM-9, in order that a demonstration flight and crash test can be completed by the end of FY 1984. The Phase II, full-scale validation portion of the program, will employ either FM-9 or that candidate fuel from Phase IIA which demonstrates the best overall performance. The three major parts of Phase II are (1) the ground and flight tests, (2) the full-scale aircraft crash test, and (3) the establishment of the final cost/benefit aspects of the fuel.

The schedule for full-scale ground and flight testing is shown in figure 3. As a precautionary measure, the fuel system in an FAA 727 aircraft will be split and the ground and flight tests will have one engine dedicated to the antimisting fuel. These test efforts are to demonstrate validity of information gained from Phase I and to assure that significant problem areas have not been overlooked.

The culmination of the development test work is the full-scale crash demonstration of an aircraft fueled with the antimisting fuel. The schedule for the full-scale crash test effort is shown in figure 4. It is proposed that an FAA 720 aircraft be impacted into a preselected course that would supply the appropriate ignition exposure to show acceptability of the fuel characteristics.

The continued development of FM-9 will be paralleled by an alternate candidate fuel evaluation under Phase IIA, figure 5. This phase will identify, investigate, screen, and develop the most promising alternate antimisting fuel candidate. Funding, as "seed money," will be made available in FY 1981 to encourage and support industry development of alternate fuels. The elements of this development process include the same basic characteristic considerations as Phase I for screening candidate fuels and candidate selection based on large-scale tests, resolution of compatibility problems, fuel specification and quality control requirements, and production/supply limitations.

The final step in the development of the antimisting fuel is the detailed compilation, analysis, and judgment process of establishing the cost of introducing and using the fuel balanced against the potential benefit in the saving of lives, recovery of equipment, and possible reduction in insurance costs. All such information will be assimilated throughout the program.

As indicated in figure 1, the efforts to date have been in the Phase I feasibility/FM-9 development area, which is presently at the mid-point of the 4-year effort. Preparations for the 727 aircraft ground and flight tests and the 720 aircraft crash tests have just been initiated. The "seed money" for developing new candidate fuel is expected to be available in February 1981.

3. PHASE I FEASIBILITY RESULTS.

The antimisting fuel work accomplishments under the MOU and the FAA program during the last 2 1/2 years by FAA, NASA, RAE, and their contractors may be categorized as flammability, rheology compatibility, and production. Currently, the major FAA contractors include Southwest Research Institute, Jet Propulsion Lab, Naval Air Engineering Center, Pratt and Whitney Aircraft, Douglas Aircraft Company (Pending), Simmonds Precision Products, Falcon Research and Development Company, and the Aerospace Corporation.

3.1 FLAMMABILITY.

The flammability characteristics of FM-9 antimisting fuel are being investigated utilizing a RAE sled test, the FAA wing spillage rig (figure 6), and various small-scale laboratory test methods. Test results with 0.3 percent FM-9 fuel have been very encouraging. The FAA wing spillage rig has demonstrated that 0.3 percent FM-9 fuel will prevent mist ignitions or, at the very worst, produce only local flame intensification at the ignition source and small self-extinguishing fireballs in the mist (figure 7) at speeds up to 120-135 knots. As speeds increase to 160 knots, the

fireballs downstream from the simulated ruptured tank increase in numbers and size. However, unlike the neat Jet A explosive mist ignition (figure 8), the propagation rate of the fireballs in the 135 to 160 knots range are relatively slow and the fires do not propagate upstream to the ruptured tank (figure 9). The crash test of an SP-2H aircraft at the Naval Air Engineering Center on November 16, 1979, demonstrated the self-extinguishing characteristic of FM-9 fuel and the slow forward flame propagation in an FM-9 fuel mist. A fireball which occurred immediately behind the aircraft (figure 10) separated and the aircraft was not damaged by the fire. Therefore, survivable crashes with impact speeds as high as 160 knots would be expected to be protected from fire damage due to mist ignition of 0.3 percent FM-9 fuel, since such fires would remain detached from the aircraft.

The overall flammability results of the FAA wing spillage rig tests are summarized in figure 11 as a function of aircraft population and landing speeds. The vertical bars represent the number of U.S. commercial aircraft at each landing speed and the dashed line shows the accumulative percentage of aircraft. For example, at landing speeds of 140 and 145 knots, 88 and 99 percent of the aircraft land at or below those respective speeds. The flammability performance of FM-9 is shown by the shaded area. At 140 knots, FM-9 concentrations of 0.3 percent or greater would prevent ignition at fuel temperature to 75° F. Likewise, at 140 knots, FM-9 concentrations of 0.2 percent or less could result in propagating fireballs.

3.2 RHEOLOGY.

The rheology and rheology related investigations of FM-9 antimisting fuel have identified a number of minor problems which require further work. The long chain polymers in the antimisting fuel are susceptible to shear degradation and some reduction in fire protection when pumped or filtered. However, intentional mechanical degradation can restore the antimisting fuel to the physical properties of neat Jet A. The viscosity of undegraded 0.3 percent FM-9 is only 60 percent greater than neat Jet A. The contact of FM-9 fuel with bulk water is also potentially a problem with possible gel deposits forming in the fuel. The heat transfer rate of undegraded FM-9 fuel is significantly less than for Jet A or fully degraded FM-9 fuel. The calibration of turbine type flowmeter is affected by the degradation level and temperature of the antimisting fuel.

3.3 COMPATIBILITY.

The compatibility investigations of FM-9 antimisting fuel have identified some required changes to the aircraft end engine fuel systems. First, some degradation will be required before the fuel enters the engine. This intentioanl degradation by mechanical means is expected to require approximately one-half percent of the engine power output. The degrader is required to overcome heat exchanger and fuel nozzle problems. The fuel nozzle spray characteristics are poor with undegraded fuel and good with fully degraded fuel. Gel formation, filter plugging, and high flow resistance can occur at certain fuel-flow velocities. Fuel system material compatibility problems have been identified with antimisting fuel producing swelling of some elastomers. Likewise, jet transfer pumps have been shown to be less efficient with the antimisting fuel. Tests with partially degraded fuel have also shown significant increases in exhaust emissions at idle engine power. However, highly degraded antimisting fuel is expected to at least partially restore the low power emission levels.

3.4 PRODUCTION.

The production investigations of FM-9 antimisting fuel have identified some potential blending and quality control problems. The fuel may be sensitive to impurities in the raw materials and possibly in the carrier fluid. This together with the bulk water and pumping, filtration, and other unwanted degradation problems are expected to require higher standards of quality control and special handling and fueling considerations compared with conventional jet fuels. In-line blending of the additive at the airport and possibly at the aircraft fueling point is expected to solve many of these problems.

4. CONCLUSIONS.

Results to date indicate that there are significant fire protection benefits and no insurmountable technical problem which would preclude further research and development for future use of antimisting fuel in commercial aircraft operations.

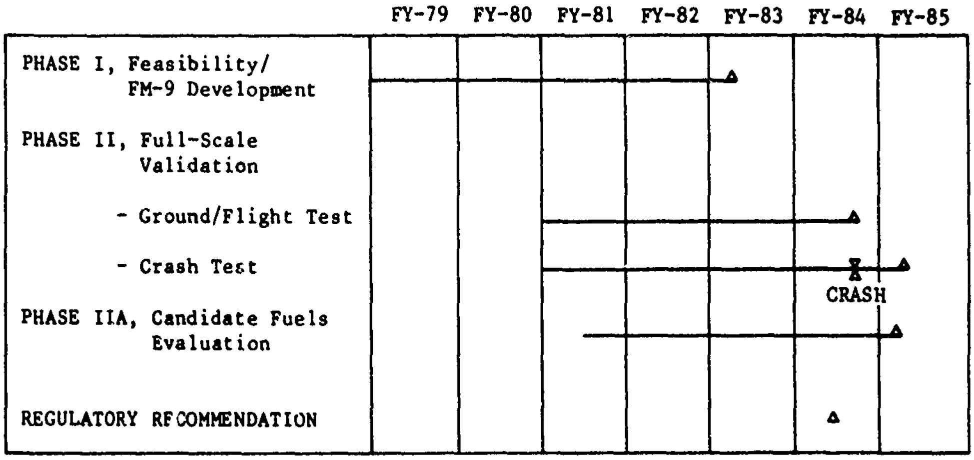


FIGURE 1. OVERALL ANTIMISTING FUEL PROGRAM PROPOSED SCHEDULING

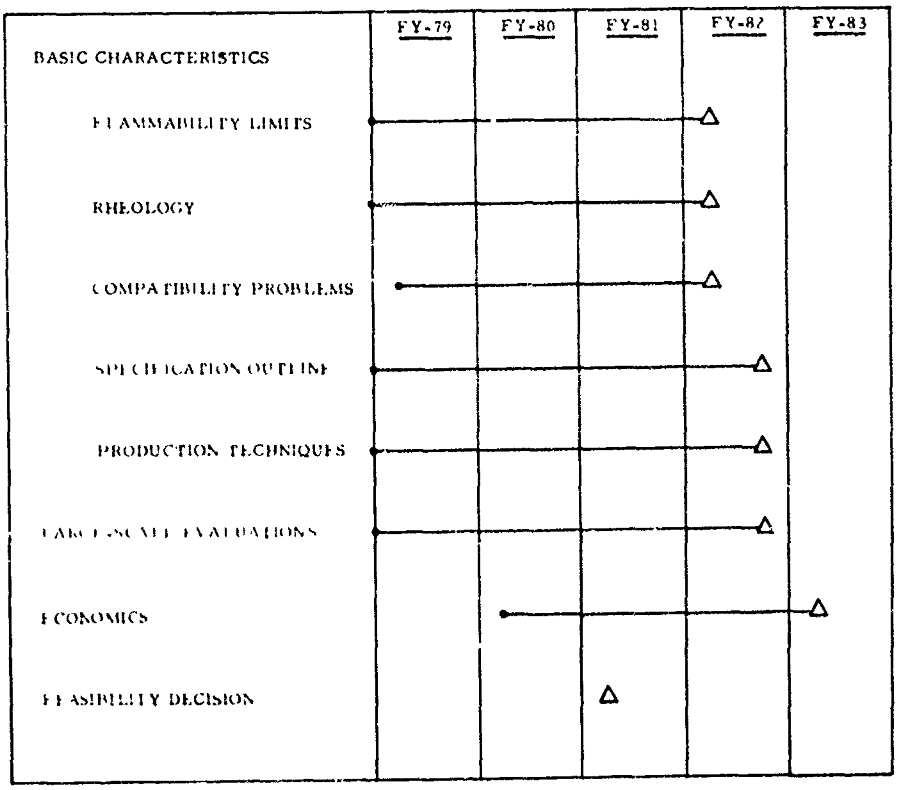


FIGURE 2. PHASE I — FEASIBILITY/FM-9 DEVELOPMENT ANTIMISTING FUEL PROGRAM PROPOSED SCHEDULING SUMMARY

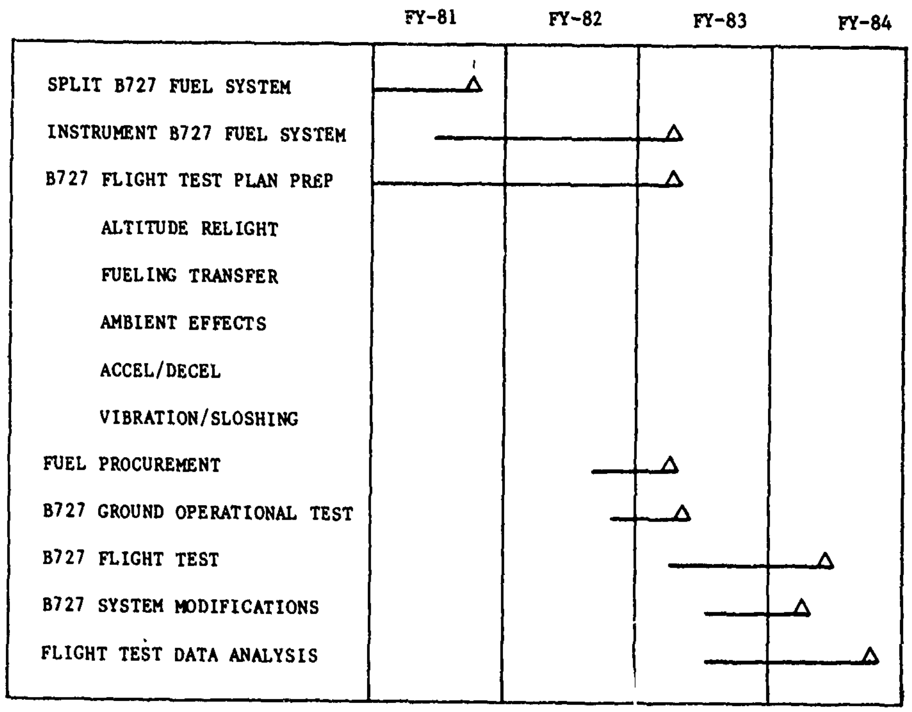


FIGURE 3. PHASE II — FULL-SCALE VALIDATION B727 FLIGHT TEST W/FM-9 PROPOSED SCHEDULING

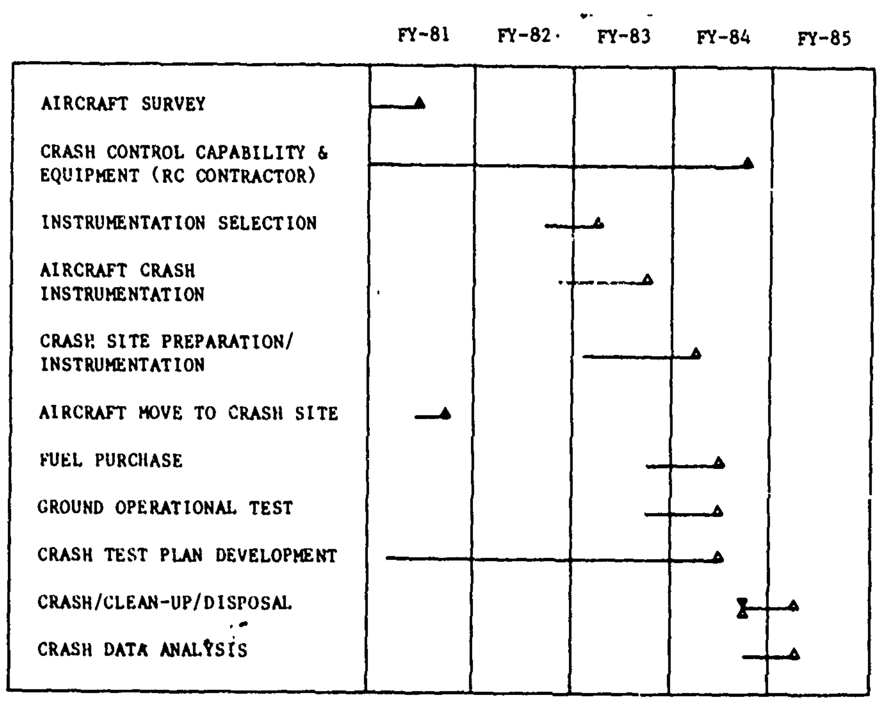


FIGURE 4. PHASE II — FULL-SCALE VALIDATION FULL-SCALE CRASH TEST PROPOSED SCHEDULING

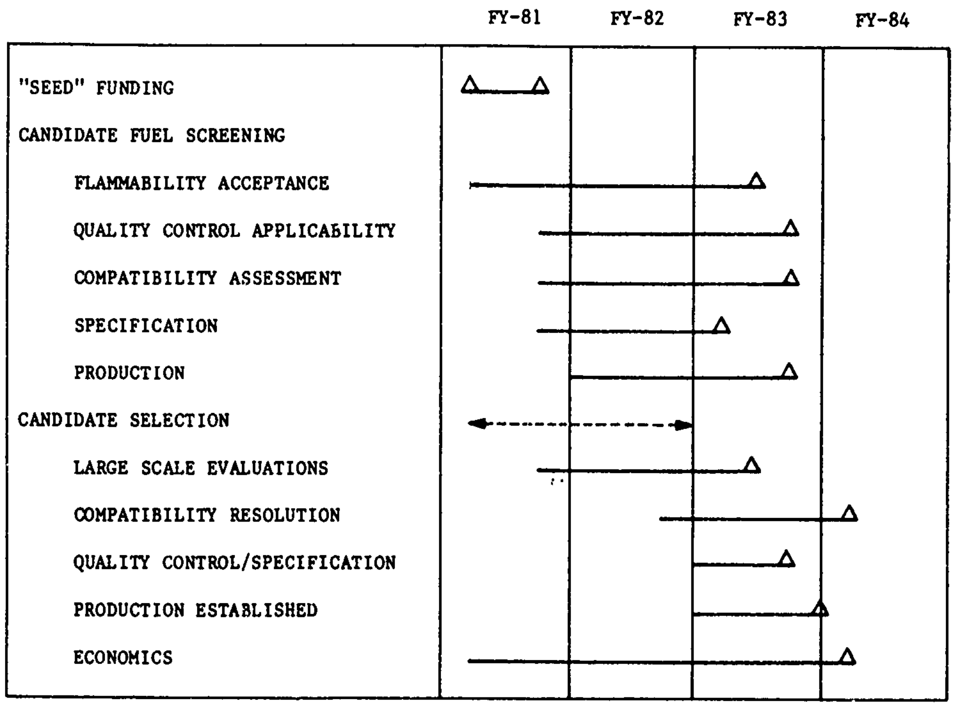


FIGURE 5. PHASE IIA — CANDIDATE FUELS EVALUATION PROPOSED SCHEDULING

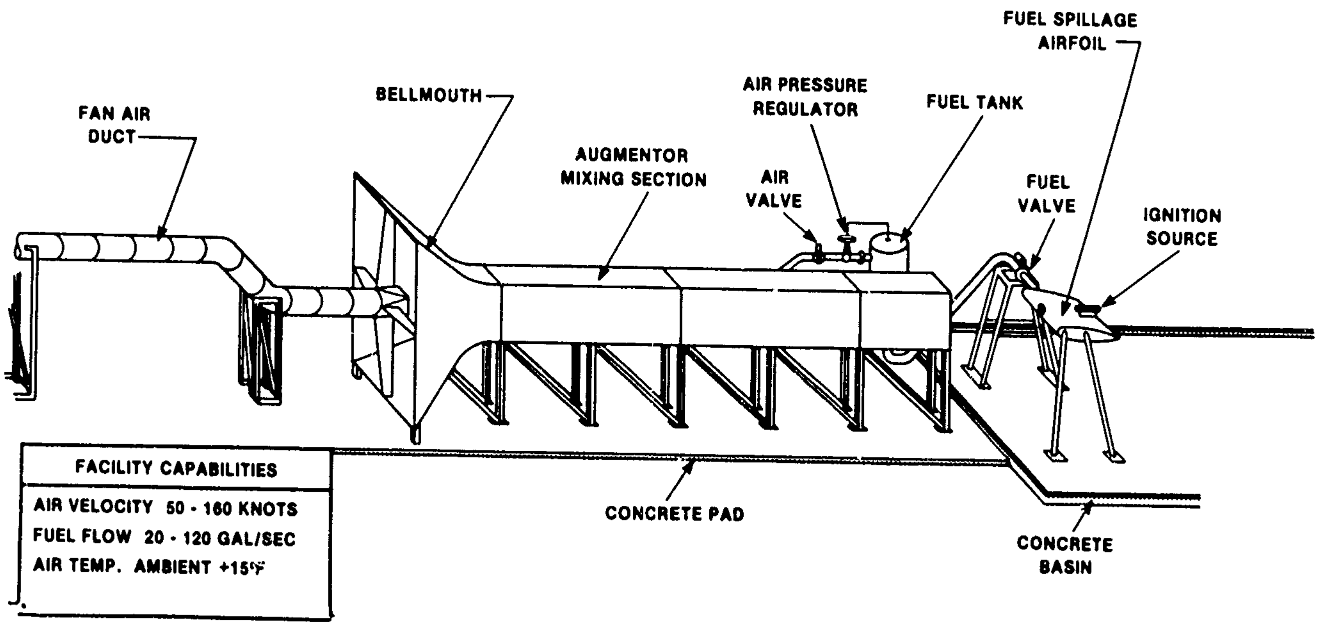
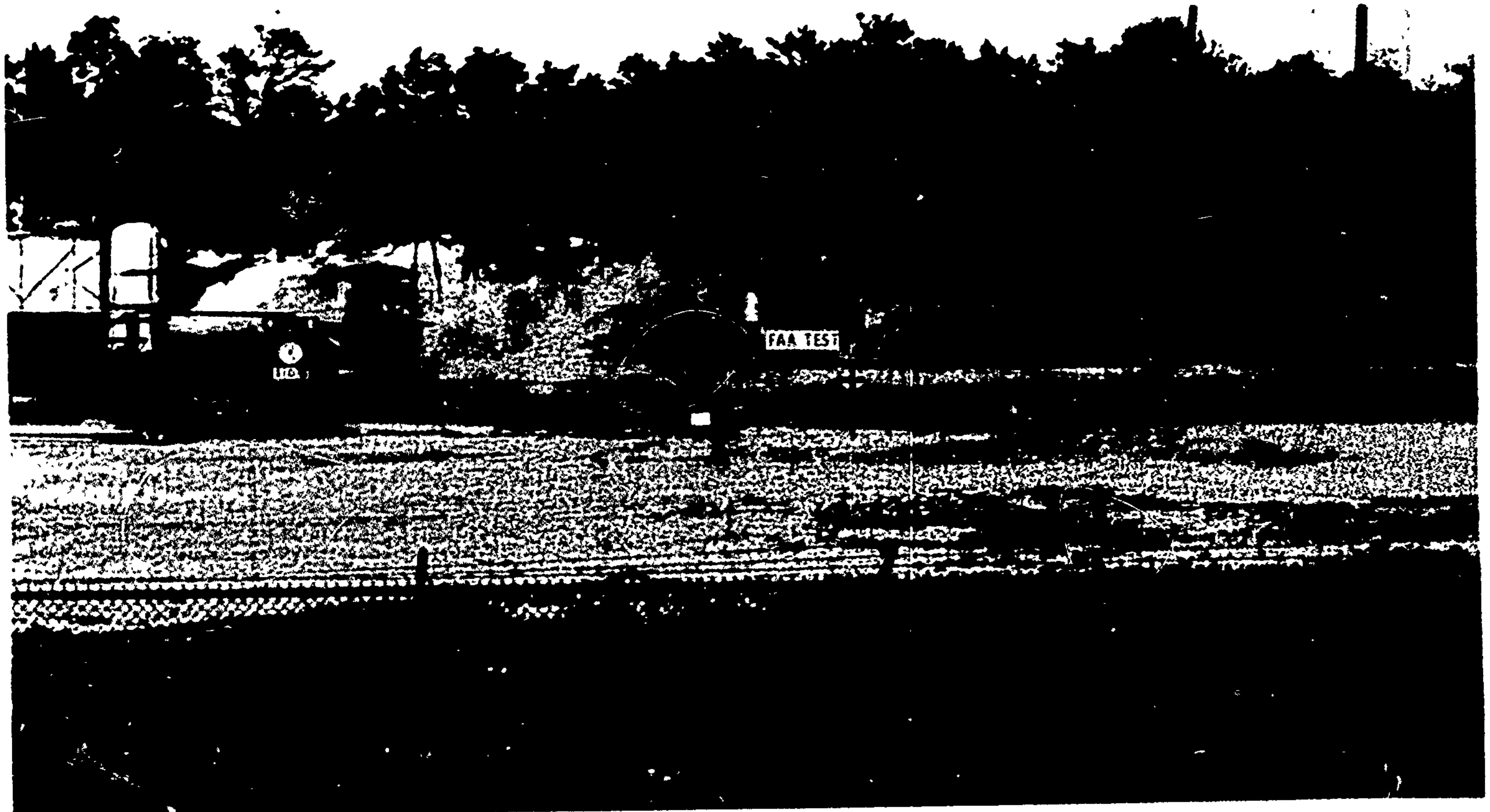


FIGURE 6. MODIFIED FUEL-WING SPILLAGE TEST FACILITY



ATLANTIC CITY, NEW JERSEY

80-3814

FIGURE 7. FM-9 FUEL PASSING WING-SPILLAGE TEST

FIGURE 8. JET A FUEL FAILING WING-SPILLAGE TEST

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FIGURE 9. FM-9 FUEL FAILING WING-SPILLAGE TEST

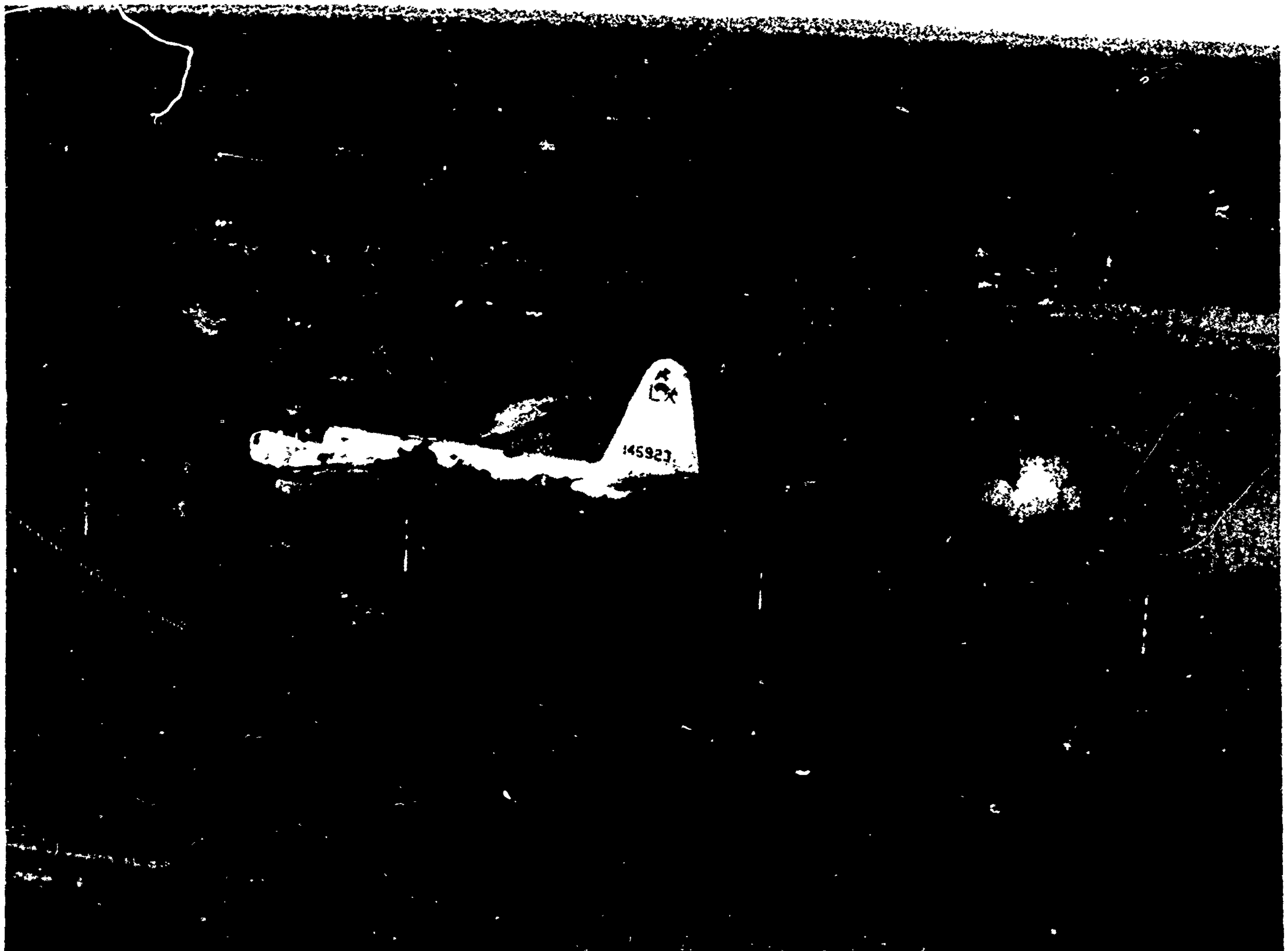

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FIGURE 10. SP-2H AIRCRAFT CRASH-TEST WITH FM-9 FUEL

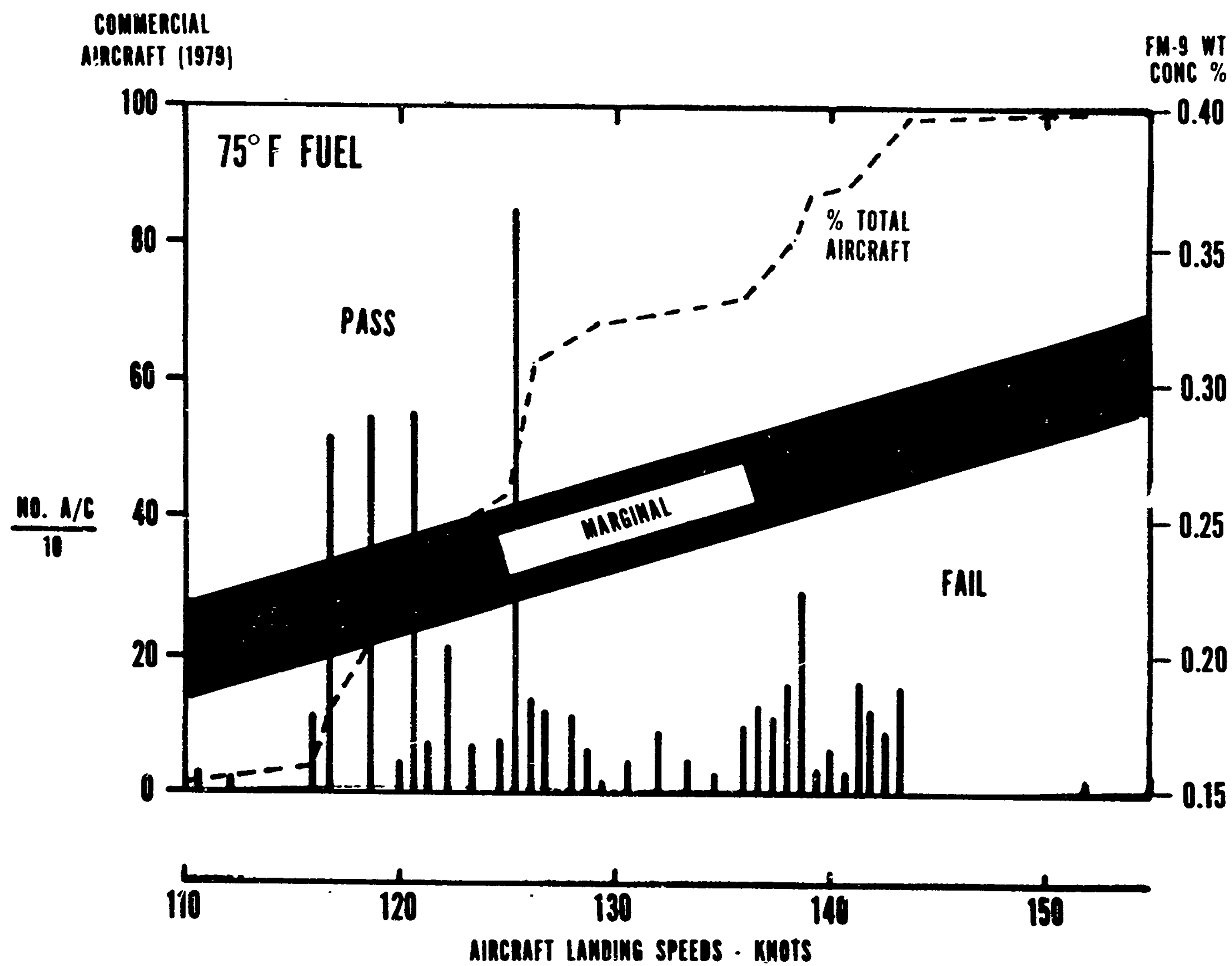

FIGURE 11. FLAMMABILITY PROTECTION OF FM-9 FUEL

Interior Coatings -- Tanks and Pipelines

James R. Griffith
Naval Research Laboratory
Washington, D. C. 20375

INTRODUCTION

The lining of shore-based fuel storage tanks of the Navy has been an item of research interest at the Naval Research Laboratory since the end of World War II. For a number of reasons this has been a problem with no apparent final solution although such a solution has been the goal. The interior of a large tank most frequently collects water in the bottom and may from time to time contain a variety of hydrocarbon fuels. Because of the wide range of chemical and physical inertness factors required, the practical considerations regarding an average contractor's ability to apply the lining properly, and the long-term performance desired, there are relatively few organic materials which embody the necessary characteristics of a satisfactory tank lining. Also, the Navy has three somewhat different types of surfaces to line -- concrete, welded steel and riveted steel. The problem of lining large concrete tanks is particularly troublesome because of the nature of the material, a lack of wide-spread commercial interest in such tanks, and the fact that available compositions that have proven effective periodically disappear from the market.

The lining of pipelines differs from that of lining steel tanks primarily with regard to accessibility to the surface to be coated and the factor of rapidly moving fuels in contact with the lining. The attention of the Laboratory has not been focused upon pipeline linings in a research program, but many factors regarding the lining of steel fuel storage tanks are obviously involved.

BASIC TANK AND PIPELINE COATING CONSIDERATIONS

Virtually all of the modern high performance coatings for severe service are based upon synthetic polymers, most of which did not exist 50 years ago. Two broad classes of these polymers may be recognized -- the so-called thermoplastics and the thermosets. The thermoplastics are based upon molecules with linear structures, and the physical consequence of this molecular condition is that these can be dissolved in solvents or melted. The thermosets are based upon molecules that are crosslinked into large network structures, and such materials are not soluble in any solvents nor can they be melted. It is thus necessary that the final chemical reactions which form the thermoset coatings occur after the precursor materials have been applied in a pre-reacted, soluble state. It is for this reason that most modern, tough coatings such as epoxies, polyurethanes and polyesters are supplied as two-component systems which are blended shortly before use. In the case of most thermoplastics, the chemical reactions are carried out in a chemical plant before delivery to a customer, and it is necessary to employ a solvent or a hot melt procedure to apply them as coatings. A prominent group of materials in this class are the vinyl resins, which were once widely used as linings for steel tanks although they have been largely replaced by the thermosets for a variety of reasons.

Most frequently, a tank lining does not ultimately lose serviceability because of chemical breakdown of the component molecules. Physical processes such as loss of adhesion, cracking, stretching or severe swelling eventually render the linings unserviceable, and it is the aim of research in this area to delay these events as long as possible. Often it is the water in the tanks, particularly in the bottoms, that is more detrimental to the tank linings than the fuels.

In the past it has been regarded as of small consequence that a large tank may leak minor quantities of fuel because the cost of a barrel was trivial compared to the total content value and it was not obvious that such leaks were environmentally harmful. In today's climate of high fuel costs and great public enthusiasm for environmental issues, demands are being made that storage tanks be absolutely leak tight. It is probably possible to achieve this goal with a new lining provided enough funds and effort are expended, but it may not be possible to insure perfect performance over long periods of time. One of the issues of the day is that of whether any level of leakage is permissible from large tanks; if so, how much, and if not, how can it be prevented within any sort of reasonable budget? The absolutely leak-tight condition can be achieved fairly realistically in closed, welded steel tanks, but it is questionable whether or not concrete tanks and riveted steel tanks can be so secured over long time frames.

THE LINING OF CONCRETE TANKS

Since the concrete tank lining problem is principally one of Navy interest, a brief discussion will suffice for this presentation. Most concrete tanks were constructed on an urgent basis during World War II when steel was short. By its nature, concrete tends to settle and crack, but many of these tanks were intended for use with black oil which had a self-sealing quality. Those used for aviation fuels in the early days were lined by a "wall-paper" technique in which sheets of polysulfide rubber were applied to the walls and floors with adhesives. Although natural rubber and neoprene were available, the polysulfides were most suitable for use in contact with aromatic aviation fuels, but the adhesives and laps presented constant problems.

After the War polysulfide became available in water-dispersed or latex form, as did many other synthetic polymers. It was found that blended latexes made the most practical and effective concrete fuel tank linings, and such materials are still in wide use. In recent years, materials supply problems, problems of adhesion to old, oil-soaked concrete surfaces, and demands that the tanks be absolutely sound have resulted in much criticism of the latex linings. Efforts are underway to replace them with less-expensive materials of better performance, but it is yet to be proven that this is possible.

LININGS FOR WELDED STEEL TANKS

The most important general tank lining problem in the future will be that for welded steel tanks. It is appropriate to ask why such tanks should be lined since it is possible to make a tank leak tight by good quality welding. A case can be made for not lining such tanks, and in the past it seems to have been the prevailing commercial view that lining was unnecessary.

Steel has one major drawback as a tank construction material -- it corrodes. Often the corrosion is concentrated in certain spots to produce pits which can proceed completely through the walls before the bulk of the steel surface is seriously affected. This type of corrosion occurs most often in the tank bottoms where water collects, but it has also been observed in the walls of floating roof tanks which are frequently exposed to the weather. The preservation of steel tanks is probably sufficient justification for the use of internal linings, but there is the additional consideration of fuel cleanliness since rust tends to sluff off and collect in tank bottoms. Good quality linings can prevent this and make the periodic cleaning of the tanks considerably less laborious.

Linings for welded steel tanks are not necessarily thick, rubbery materials, as are concrete tank linings, and coatings which are much like conventional paints are used. In the United States, the epoxy resins are probably the most widely used linings for welded tanks, and there is a strong preference for these in some quarters. However, the Navy has used certain polyurethanes in welded steel tanks over the last two decades with excellent results. It has been our contention that the Navy stance on the question of epoxies versus polyurethanes is justifiable on theoretical grounds as well as the practical experience of long-term performance. The theoretical argument is that polyurethanes come to a state of chemical stability very quickly after application to tank walls because of intrinsic qualities of the materials used, whereas epoxies continue to react slowly over long time periods and are more prone to eventual embrittlement. In any event, to our knowledge there has never been an instance to date in which a properly applied polyurethane of acceptable composition has failed to render satisfactory long-term performance in the field, whereas there have been several premature failures of epoxy linings. The variable of contractor error is difficult to access after the fact with regard to such failures, and it is of utmost importance that knowledgeable inspectors oversee the lining operation when any type of lining is applied to a large fuel storage tank.

During preparation for an unusually large tank lining project, research in the late 1950's was directed into some unusual and somewhat imaginative areas in the search for super linings for steel. It was discovered that a process of spraying aluminum on a prepared steel surface (metallizing) provided a highly superior base for the subsequent organic lining, and it was projected that this procedure could double the life of a lining. Although this measure was not generally adopted at that time, probably because of initial cost factors, a few tanks were metallized on an experimental basis. A review of these was made after 13 years of service, and the conclusion was drawn that the original projection of the effectiveness of the process was correct. Today there is a renewed interest in the metallizing process, particularly for the bottoms of welded tanks with basically sound steel on the floors, and the capabilities for correctly applying sprayed metals are expanding rapidly. It is our belief that great savings can be effected in the long-term if the barrier of initial cost is considered in a statesman-like manner.

Welded tanks with unsound floors due to pit corrosion or severe deterioration in the bottoms pose a special problem. This has sometimes been addressed by the pouring of new concrete floors in steel tanks, but the

resulting lining problems have been difficult to address because of the disparate nature of two materials and the lining interfacing necessity. It is probably preferable to rebuild a steel floor with reinforced polyesters, which is a form of rebuilding a plastic tank within a steel one. An alternative which is probably justifiable on a long-term basis is the removal of steel in the floors, replacement with new plates, metallizing, and coating with polyurethane. Although this would be a relatively expensive process, it should provide a tank for worry-free service long into the future if done properly.

LININGS FOR RIVETED STEEL TANKS

The production of fuel storage tanks by riveting steel is a past art; however, there are many good tanks still in service with this construction. Linings for these tanks are usually "high-build" coatings, that is, those which can be applied thickly in one application, in contrast to the thin linings used in welded tanks. This is made necessary by the many sharp edges at plate overlaps and by the tendency for leakage around the rivets.

At the present time, there is some unresolved question regarding the best materials for use in the lining of riveted tanks. Several types of reinforced polyesters are available, some with fiber reinforcements and some with flakes; there are high-build epoxies and several types of polyurethanes that can be applied thickly. Floating roof tanks of riveted construction pose a special problem because of the scuffing action as the roof rises and falls rubbing against the coating on internal projections. Service experience is now being collected on all three classes of coatings materials, but it will be several years before clear choices can be made. It is expected that all three -- epoxies, polyurethanes and polyesters -- will give reasonable service in these tanks, although there will probably be clear preferences not yet evident. To date there are no instances to our knowledge in which aluminum metallizing under organic coatings of a high build character has been attempted in riveted tanks, but this possibility is one for future consideration which may offer as much promise in these tanks as in those of welded construction.

PIPELINE COATINGS

In any type of high-quality coating of steel, it is essential that the entire surface be prepared to receive the application and that the material be applied as a continuous layer. These problems have been addressed in some ingenuous ways for the internal coating of in-place pipelines. The use of "pigs" (fitted plugs which can be forced through the pipeline by pressure) as cleaners and as paint applications is a specialized art which has been developed by several companies involved in this work. Also, a special form of sand or grit blasting in which the particulate matter is forced through long distances of pipe by high pressure gases, thereby repeatedly striking the interior surface at oblique angles, is another specialty procedure. The problem of knowing with certainty that all of the surface is prepared and coated uniformly is of obvious concern, particularly where there are surface irregularities. This is usually addressed by the installation of removable short segments of the pipe which can be examined periodically.

The companies doing this type of work appear to use epoxy coatings exclusively, although it would seem possible that polyurethanes and polyesters could be adapted. The flow properties of the coating are obviously important if the pig applicator is to lay down a uniform layer without excessive sag or drip. The smoothness of the coating is important since any projections into the flow of fuel are likely to cause local turbulence which would increase the energy required for throughput in the line.

At present we do not have long-term comparisons for pipeline coatings, and there are a number of possible variables which could be of concern aside from initial cost considerations. The questions of whether or not the fuel were periodically contaminated with water and if at times the flow would cease and allow water to settle may be important to long-term serviceability. Cylindrical fuel storage tanks virtually always rust in the bottoms first, and it is not uncommon that severe local pitting occurs there while the bulk of the steel is in good condition. In pipelines carrying fuel continuously this should not be a problem, particularly if the fuel is dry of water. On the other hand, fast flow of fuel should tend to wear a coating at some rate, and more so in turbulent areas. Local corrosion or wear on the lined interior of a pipe may limit the effectiveness of such coatings, but our experience is too limited to judge these factors.

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Dr. Griffith has been a regular contributor to the programs of the Organic Coatings and Plastics Division of the American Chemical Society for over 20 years and has served three terms in various offices of this Division. In 1979 he shared the Hillebrand Award of the Chemical Society of Washington for his work in the syntheses of innovative polymers.

ENERGY PROBLEMS IN THE SOVIET UNION

PRESENTED BY

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INDUSTRY-MILITARY ENERGY SYMPOSIUM
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Energy Problems in the Soviet Union

Summary

P.S. Neporozhniy, Minister of the Electric Power Industry in the USSR and a leading energy spokesman, recently stated "that an energy crisis does not threaten the USSR, but it would be wrong to think that we have no problems in fuel and energy supply." We share Neporozhniy's concern as we believe the present enviable Soviet energy position is about to undergo a change for the worse that will last through the 1980s.

Currently, however, the Soviet Union is the only major industrial nation in the world that is self-sufficient in energy. It leads the world in production of oil and coal, is second to the United States in natural gas production, and third in generation of electricity from nuclear power plants. Moreover, the USSR this year is a net exporter of 4 million barrels per day (b/d) of oil equivalent consisting of:

Oil	2.9 million b/d
Natural gas	0.8 million b/d
Coal and coke	0.2 million b/d
Electric power	0.1 million b/d
	4.0 million b/d

Although the potential resource base -- oil, gas, coal, hydro power -- is large, the bulk of these resources are located in eastern regions far from major consuming areas and where the severe climate and difficult operating conditions impede their

development. Together with the high costs of exploration and development of such resources we see a number of other problems facing the Soviets in this decade that will restrict growth in energy supply and constrain economic growth. A prospective decline in oil production is part of the problem; stagnant coal production and below plan growth of nuclear power also loom as significant difficulties. Only natural gas production is meeting or exceeding goals, but it cannot bail out the USSR because gas-oil substitution possibilities will remain severely limited through much of the 1980s. Meanwhile, energy savings through conservation have been and will continue to be limited.

The viewgraph shows the contribution of the various primary energy sources for 1965, 1970, 1975 and our estimates for 1980, 1985, and 1990. Average annual growth rates of energy production were about 5 percent during 1966-75, about 4 percent during 1976-80, and we foresee sharp declines for the 1980s -- perhaps 1-2 percent of increases. Oil's share of total output rose from 34 percent in 1965 to about 43 percent in 1980 and if our predictions are valid, will decline to about 36 percent in 1985 and 28 percent in 1990. During the same period, the share of gas will continue to rise from 15 percent in 1965, 26 percent in 1980, and some 36 percent in 1990. Coal's contribution has declined from 41 percent in 1965 to about 25 percent in 1980 and should remain at this level, assuming that many of the problems facing the industry can be overcome by the mid 1980s and production will

reach about 875 million tons in 1990. Nuclear power growth will be significant during the 1980s, but probably will account for only about 5 percent of total energy production in 1990.

Major Sources of Energy

Now that I have given you the big picture, let me discuss briefly the outlook for the major energy sources and conclude with my impressions of Soviet opportunities for energy conservation and fuel substitution.

1. Oil

The major topic of interest is that of the Soviet oil industry and our estimates of future production. At the present time oil output is about 12 million b/d (includes crude oil and gas condensate). This production is used to satisfy domestic demand, provide for the bulk of the needs of Moscow's Communist allies, and to earn hard currency from sales to the West. In 1979, net Soviet oil exports totalled about 3.1 million b/d; 1.9 million b/d to Eastern Europe and other Communist countries and 1.2 million b/d to the West. Almost 1 million b/d was sold to hard currency countries earning about $10 billion, almost half of Soviet hard currency earnings from commodity sales to the West.

Development of the Soviet oil industry as a modern, nationwide industry is a phenomenon of the post World War II era. During the 1950s and the 1960s the USSR was able to raise production from older areas in Azerbaydzhan and North Caucasus near the Caspian Sea, in Central Asia, in the Ukraine, and in Belorussia. (See map.)

The major Soviet development effort, however, was concentrated in the big, prolific fields of the Volga-Urals region. The supergiant field at Romashkino (in Tatar ASSR) by itself was a major factor in Soviet success. In 1970 when its output peaked at more than 1.6 million b/d, it accounted for almost one-fourth of total national oil production. After 1975, this major field and other giants in the area began to decline rapidly after two decades of intensive production by water flooding. In the mid-1960s highly productive large deposits, including the supergiant Samotlor oilfield with estimated resources of 15 billion barrels, were discovered along the Middle Ob River area in West Siberia. Infrastructure costs were high, but by drilling a relatively small number of wells per year in West Siberia, the Oil Ministry was able to keep overall oil output rising during the 1970s. This comfortable situation began to change in recent years, however, as most of the larger and most productive reservoirs in West Siberia were approaching complete development and new reservoirs are of poorer quality. West Siberia is to account for about half of Soviet oil output this year.

Now, oil production is declining in all of the major oil producing regions except West Siberia, and even there gains are uncertain with the peaking of the supergiant Samotlor field (about 3 million b/d). Samotlor, which has accounted for a large share of production growth in recent years, is likely to slump in the next year or so and then fall rather rapidly. Meanwhile, the decline already underway in the large older producing regions probably will accelerate as reserves are depleted.

As a result chances are good that Soviet oil production will peak this year at about 12 million b/d, level off for a year or two and then decline, perhaps to a level of 10-11 million b/d by 1985. Beyond 1985, production will continue to decline, although at slower rates as the Soviets lack the accessible high-flow oil reserves to sustain production. In the long run, the future of Soviet oil production depends on success in discovering and developing oilfields in new areas -- primarily in the Barents and Kara Seas the deep waters of the Caspian Sea, Eastern Siberia, and the deep onshore Caspian depression. None of these areas have been explored intensively and any new finds would have little impact on oil production until the late 1980s or early 1990s. Development of the offshore areas and deep onshore basins will require Western equipment and technology. Even so, much of the technology for exploring and developing resources in the Barents and Kara Seas is not available in the West, thus complicating the ultimate exploitation process.

If the Soviets manage to find and develop large deposits in new areas, the oil production decline we predict could be halted or even reversed temporarily, but probably not before the 1990s.

The Viewgraph illustrates very roughly the importance of the West Siberian region in current and short run future of Soviet oil production.

2. Coal

My remarks on the Soviet coal industry are based on a recent study we have prepared, USSR: Coal Industry Problems and Prospects, March 1980. In this report, we say that coal will not be the

solution to the energy crunch during the 1980s. There are two main reasons for this: (1) It would be impossible to substitute coal for oil fast enough, and (2) even if large scale interfuel substitution were possible, the coal industry is poorly equipped to increase production sharply at least through 1985.

I would like to discuss three key subjects in this brief presentation (1) current Soviet production (2) problems the Soviets are having with the industry, and (3) plans for the development of new basins in Siberia.

It is important to note that in the aggregate, the USSR does not suffer from a lack of coal. On the contrary, Soviet coal reserves are enormous. At a minimum, proved reserves total some 250 billion tons or over 300 years supply at current rates of production. Indicated reserves are estimated at some 5.7 trillion tons.

Production: We estimate that Soviet coal production will amount to about 720 million tons in 1980, 25 million tons short of the revised annual goal and almost 90 million tons short of the original target. (See viewgraph.) Production was planned to increase about 3% per annum during 1976-80. It looks as if it will increase by about half a percent per annum during this period.

Problems: The Soviet coal industry is facing a series of problems many of which have been years in developing: (1) mining conditions are worsening, especially in older basins (2) reduction in the work week from 36 to 30 hours the the Donetsk Basin (Donbas)

(3) shortages of labor, parts, tractors, excavators (4) snarls in rail transport (5) rise in mine depletion -- presently depletion offsets about two-thirds of annual commissionings, and (6) inadequate past investment -- growth in investment has only recently started to pick up but even so, about 75 percent of annual investment simply goes into maintenance.

Problems are highlighted in the Donetsk basin, which accounts for about one-third of the country's coal production and about 45 percent of the coking coal. In general, the seams are thin (less than 1 meter), deep (about 700 meters), steeply pitched (limiting the use of mechanized equipment), and gassy (about 60 percent of Donbas mines contain dangerously high concentrations of methane). Output peaked in 1977 at 223 million tons. It fell to 212 million in 1978 and about 207 million tons in 1979. We believe this trend will continue and output may be about 180 million tons by 1985. Costs are rising sharply in the Donbas and huge investments will be required just to prevent the backslide from accelerating.

Siberian Development: The Soviets clearly are counting on new Siberian deposits to account for practically all of the growth in future coal supply. In the near term (until 1985) the Soviets will emphasize the development of the Ekibastuz and Kuznetsk basins. The huge Kansk-Achinsk basin probably will not be developed until after 1990 (See map.) The Kuznetsk basin will prove especially critical in terms of the USSR's supply of coking coal. It now accounts for about 35 percent of national supply and has accounted for all of the growth in output in recent years.

Despite problems, cost and investment considerations clearly favor Siberian development. For example, costs of strip mined Siberian coal is 2-6 times lower, than underground coal in the Western part of the country, and investment is anywhere from 3-9 times lower.

The huge Kansk-Achinsk basin typifies many of the problems the Soviets will face. The basin has a production potential of 1 billion tons per year according to Soviet claims. The Soviets will have to overcome a series of problems before large scale production can be achieved. The coal is subject to spontaneous combustion and freezing and thus cannot be shipped more than a few hundred kilometers. The Soviets do not have boilers adapted to this coal and probably won't have for at least a decade. They are also years away from mastering the technology to transmit power, which would require construction of 2200-2400 kv dc lines. This technology probably will not be available until the turn of the century.

In summary, coal resources are available if the Soviets decide to emphasize output of this energy source. However, the effort will be enormously expensive and take years before it can substantially improve the energy situation. The present indications are that coal's share in the Soviet energy balance will not change much, at least during the 1980s.

3. Natural Gas

Let's turn now to natural gas where the picture is extremely bright for the USSR in contrast with that of the other major fuels. The Soviets are bullish on the future prospects for gas production. They are the world's second largest gas producer behind the United States and should pass the US by the early to mid 1980s.

For the last three years production surpassed the plan, reaching 407 billion cubic meters (bcm) [14.4 trillion cubic feet (tcf)] in 1979. In fact, the increase in production recorded in 1979 -- nearly 35 bcm (3.4 bcf/d) -- was a Soviet record. Production this year is likely to again meet or surpass the target of 435 bcm (15.4 tcf). Over the past 15 years, production has grown at a 9% average annual rate, about 50% higher than that recorded by the Soviet oil industry.

Unlike oil, where we believe proved reserves are limited, gas reserves are not a problem. The USSR has, according to their estimates, more than one-third of the world's gas reserves. (See viewgraph.) The last reported figure was for year-end 1977 in which reserves stood at 29 trillion cubic meters (tcm)(or more than one quadrillion cubic feet.) These reserves are highly concentrated, however. More than 80% are located in West Siberia, straddling the Arctic Circle. (See Viewgraph.) This makes their development both difficult and costly. The Minister of the Gas Industry has remarked that he would gladly trade half of the gas reserves if they were located further West near the population centers.

Turning to the regional production pattern, we find that West Siberian gas, as with oil, now accounts for all growth in production in addition to offsetting declines in other regions. (See Viewgraph.) In 1980, West Siberia will show a production increase of 41 bcm (4.0 bcf/d), while output in all other regions will decline by 13 bcm (1.3 bcf/d). West Siberian production is also highly concentrated -- only three fields out of more than two dozen giants and supergiants have been put on stream. One field alone -- the supergiant Urengoy -- which may be the largest in the world -- is expected to be producing 160 bcm (5.6 tcf) by 1982 or 1983. That amount is equivalent to the combined 1978 gas production of the Netherlands and Canada.

In the other major regions output is stagnating or declining. Central Asian production could peak in the next couple of years. In the Ukraine and Caucasus regions production is already on a steep decline.

Despite the rosy future for gas vis-a-vis the other fuels, a number of worrisome problems are emerging. Development costs in Siberia are soaking up investment funds at a rapid rate. Investment costs for new pipeline systems are a major factor as greater volumes of gas are sent over longer distances. The average distance gas is piped will reach nearly 2,000 kilometers this year, nearly double what it was in 1971.

Infrastructure development is also a problem. Road construction in the north can cost upwards of one million dollars per mile and explains why there is a shortage of all-weather roads.

Most supplies are brought in by rail and sea and large quantities of equipment are sent in by helicopter at great expense. A permanent electric power supply is also lacking in the Siberian gas region. Finally, labor turnover averages nearly 70 percent a year because of inadequate housing, medical, and recreational facilities. Unless the Soviets take steps to solve some of these trouble spots, future gas production could be adversely affected at a time when the Soviet Union can least afford it.

Although gas will provide the lion's share of overall energy increases in the USSR in the 1980s, it cannot fully compensate for the poor performances of the oil and coal sectors. As an illustration, for gas production to reach 600 bcm (21.2 tcf) by 1985 will require annual growth rates of more than 6.5% over the next 5 years. This is a formidable task and about the best the USSR can hope to achieve. Such a performance would mean an energy increment of more than 2 million barrels per day of oil equivalent (b/doe).

The USSR is embarking on a program of increasing gas exports. Eight long-term agreements were signed with West European countries during 1968-75 which provide for deliveries of a total of 26 bcm (917 mcf) annually. All of these deals included shipments of pipe and pipeline equipment in exchange for Soviet gas. Now a new deal is being discussed with the same countries that involves construction of a new Soviet export pipeline and delivery of an additional 40 bcm (1.4 tcf) per year sometime in the mid-1980s. By the late 1980s Soviet gas exports to the West would exceed 1 million b/d of oil equivalent and earn some $13 billion (assuming current prices).

4. Nuclear Power

The Soviets continue to assign a high priority to nuclear energy development but its role in energy output will be minor during the decade of the 1980s. Output of nuclear-generated electric power was about 55 billion kilowatt-hours (kwh) in 1979, accounting for less than 1% of primary energy production and only about 4% of total electricity output. Total installed capacity amounts to about 10,000 MW -- less than 9% of the world total and roughly the size of the French program. There are currently 9 operating nuclear power plants -- mostly in the European USSR with another 2 planned to go into operation this year. (See map.)

By comparison, the US has a total of approximately 54,000 MW of installed nuclear power plant capacity. It produced 276 billion kw-hr in 1978, equal to 12% of total electricity output and about 4% of total energy.

Despite the glowing vistas portrayed by the Soviets about the future role of nuclear power in the USSR, their nuclear program will remain relatively small because of an inability to produce the necessary equipment. Projections now call for 35,000-40,000 MW of capacity by 1985 and 100,000 MW by 1990. By 1985, nuclear-generated power will reach about 200 billion kwh -- still only 3% of total Soviet energy production. By 1990 this figure may reach 350 billion kwh. Although such an increase entails an impressive 18% annual growth rate over the next 11 years, nuclear power will be providing only about 5% of the USSR's primary energy output by 1990.

The Soviets have cited a number of problems responsible for the delays in accelerating their nuclear power program including high capital cost, a shortage of skilled manpower, and continuing technical and siting problems. It takes 7-9 years to build a nuclear power plant in the USSR, about the same as in the US. A major bottleneck is a shortage of manufacturing capacity for reactor components and equipment. The Izhora heavy equipment plant in Leningrad is the only Soviet plant now producing nuclear reactors. The plant has a capacity to turn out 5-6 reactors a year but produced only 3-4/yr in the late 1970's. A huge new plant, known as Atommash, is under construction at Volgadonsk but it is 2 years behind schedule. It will be the USSR's principal manufacturing complex for nuclear reactors and components of 1,000-MW and 1,500-MW capacity. The first reactor will not be completed until 1982 and the plant will not reach its full capacity to produce 8,000 MW per year until after 1985.

During the past year several Soviet energy specialists have expressed apprehension about the environmental consequences of the Soviet nuclear power program in the densely populated areas of the European USSR. We doubt, however that the Soviet leadership will be swayed by such concerns from proceeding with established development plans.

5. <u>Hydroelectricity</u>

Hydroelectric power had been the priority development sector for years until reliable nuclear power displaced it. The Soviets were understandably attracted to the low electricity production

costs from hydro. Future growth of the hydro share of electric power will be increasingly difficult because exploitable resources in European areas of the USSR are almost entirely utilized.

The power ministry projects a hydro capacity of 90,000 MW by 1990 which could be attained if all the projects now underway were pushed to completion. But the pace of hydro construction makes it likely that hydro electric power will continue to provide 13-15 percent of total electric power through the 1980s with 75-77,000 MW installed by the end of the decade. Although only 13 percent of Soviet hydro resources are now exploited, rapid growth of the remaining resources is precluded by the long distances from consumers, lengthy construction times, and relatively high cost of hydro projects.

During the 80s most new hydroelectric development is expected in Central Asia, East Siberia and the Far East where most exploitable water resources are located. Use of the hydro resources in the European USSR will be largely limited to the Caucasus and northern regions, away from areas of greatest power demand. Long range Power Ministry plans call for the exploitation of the Angara-Yenisey river system in Siberia where nearly one-quarter of the USSR's hydroelectric resources are located. However, studies done for Gosplan show that long-distance transmission of electric power from hydrostations in Siberia to the central industrialized regions will not be economically feasible at least through the late 1980s.

Conservation and Substitution

A. Conservation

The Soviets will attempt to conserve energy in the 1980s by using less scarce resources -- primarily capital and fuels of lower calorific content -- in place of energy sources in tight supply. The USSR could also reduce consumption by switching to less energy-intensive economic activity, notably light industry. Under the likely continued emphasis on heavy industry, however, the leading conservation approaches are (1) substitution of other fuels for oil, and (2) more efficient use of energy inputs, primarily through technological change embodied in new capital construction.

Neither effort will have a strong impact on energy consumption much before 1990. Soviet conservation potential is limited in the short-run by the relatively high efficiency of several important energy-intensive industries and by the relatively small amount of energy consumed by residences and transportation, two crucial areas for conservation in the West. Most Soviet conservation opportunities are long-run in nature and exist in heavy industry, where technological difficulties, high costs and inefficiency engendered by the economic system will seriously constrain conservation efforts throughout the 1980s.

Consumption Patterns

The Soviets use energy in ways that will minimize some important conservation opportunities. Soviet industry consumes a much larger portion of available energy than in the West. (See viewgraph.)

Industry and electric power generation in the late 1970s consumed between 60-70 percent of total energy output in the USSR while the same sectors in the West use roughly 50 percent. The share of total energy use by Soviet residential, commercial and transportation sectors, which present relatively greater opportunities for immediate cutbacks, is comparatively small. Stoves in individual apartments have been consuming over two-thirds of the fuels used residentially. Although such heating is less efficient than that from centralized gas- or oil-fired facilities, the predominant stove fuels have been of non-commercial quality, such as firewood or low-grade coals. Further gasification and electrification of residences thus will only increase the demand for commercial fuel during the 1980s. Soviet transportation uses far less energy than its Western counterpart. Use of private automobiles will remain far below the US level through 1990. Trains rather than trucks provide the dominant mode of Soviet commercial transport and are fairly energy-efficient. Some potential remains for electrication of intra-urban and cross-country transportation, but the oil freed up would not cover any substantial shortage in oil supply.

Several important industrial energy users have attained relatively high efficiency rates that could not be much improved in the short-run. The Soviets are world leaders in cogeneration -- the production of space heat by thermal electric power plants -- which has raised considerably the efficiency of those power facilities in comparison with the West. In the

mid-1970s cogeneration plants represented almost 40 percent of Soviet capacity for thermal electricity generation. The energy efficiency of some basic processes in steel making is already high and can be improved substantially only with widespread introduction of new equipment.

B. Interfuel Substitution

The Soviets want to substitute other fuels for oil but will be unable before 1990 to do so substantially. The primary effort at substitution will involve large-scale boilers, which consume approximately one-third of total energy supplies in providing steam and heat for electric power generation and for industrial and residential uses. Even though boilers present one of the largest potentials for replacing oil in the 1980s, however, the substitution of other fuels faces several constraints.

Coal-for-oil substitution poses serious technical problems that make it an unlikely solution in the coming decade:

- Bottlenecks in the production and transport of Siberian coal will prevent an increase in output sufficient for widespread substitution.

- Conversion of oil- or gas-fired boilers to coal would require massive investment in new equipment and infrastructure and involve downtimes of several years.

- The most likely increase in coal-fired boilers will come via the construction of new power plants, primarily near Siberian mines. Their construction will take much of the decade, and start-up could be seriously delayed by

the lack of high-voltage, long-distance transmission lines. Relocation of industries near Siberian power plants could circumvent the transmission line bottleneck but would still require most of the decade to accomplish and might not be economically rational.

One possible quick-and dirty fix involves using a coal-oil mixture in existing oil-fired boilers. Although it would be only a short-run solution, it could reduce oil consumption at given plants by up to 50 percent. The technique is still in the experimental stage in the West, however, and the Soviets have not widely discussed it.

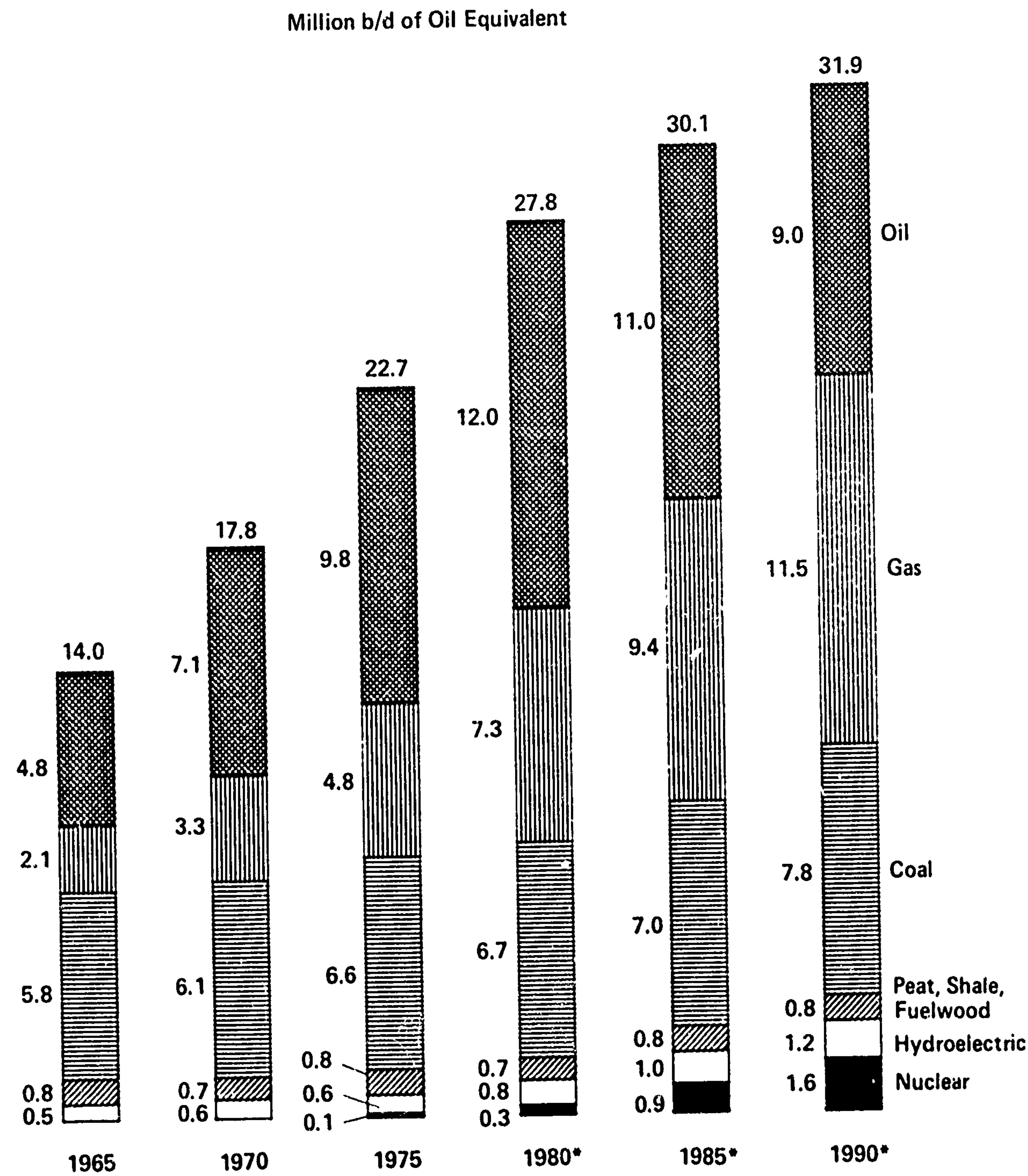
Gas-for-oil, a more promising approach, is apparently the one on which the Soviets are focusing. Oil-fired boilers can be converted to gas within a matter of days in some cases, and many Soviet electric power stations are already capable of burning either fuel. Gas storage and distribution capacity, however, will not grow sufficiently before 1990 to provide reliable year-round supply to many industrial and consumer users. Since gas, unlike oil, is not easily stored and thus is not hoardable, many industrial consumers will resist relying on it. Gas supplies may increase enough to reduce the months in which duel-fired boilers must burn oil, but massive substitution is unlikely before late in the decade.

C. Efficient Use of Energy

The other major Soviet approach to conservation is to reduce the energy consumed in productive activity. Their primary solution is to introduce new technology into energy-intensive processes, in effect substituting capital for energy. The short-run substitutability of nonenergy inputs, however, is fairly low. Although the Soviets cite many minor potential improvements of existing capacity stock in metallurgy, electric power generation, machine-building transportation and other sectors, the resulting aggregate savings of energy would be relatively small.

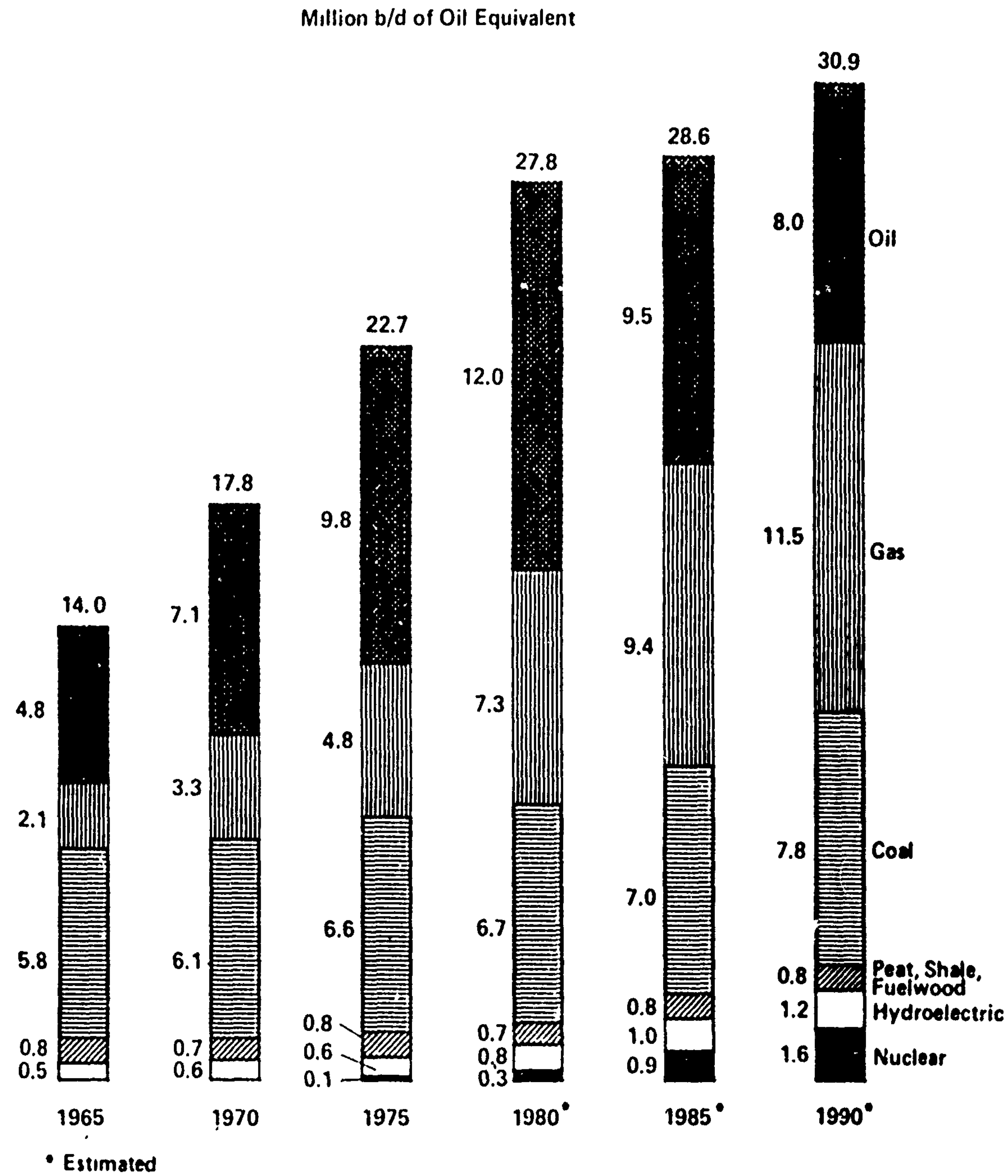
Any serious effort at raising energy efficiency will require massive capital investment extending over most of the decade. Blast furnaces used in making pig iron represent one of the more energy-intensive industrial processes. Soviet furnaces, however, are already run fairly efficient, and substantial improvement in energy use could come only from installing new, often larger units. Replacement of less efficient open hearth steel-making furnaces by basic oxygen and electric furnaces similarly will take much of the decade. Substitution of larger, better constructed boilers for production of power and heat will require improved steels that are in insufficient domestic supply.

USSR: Primary Energy Production



*Estimated

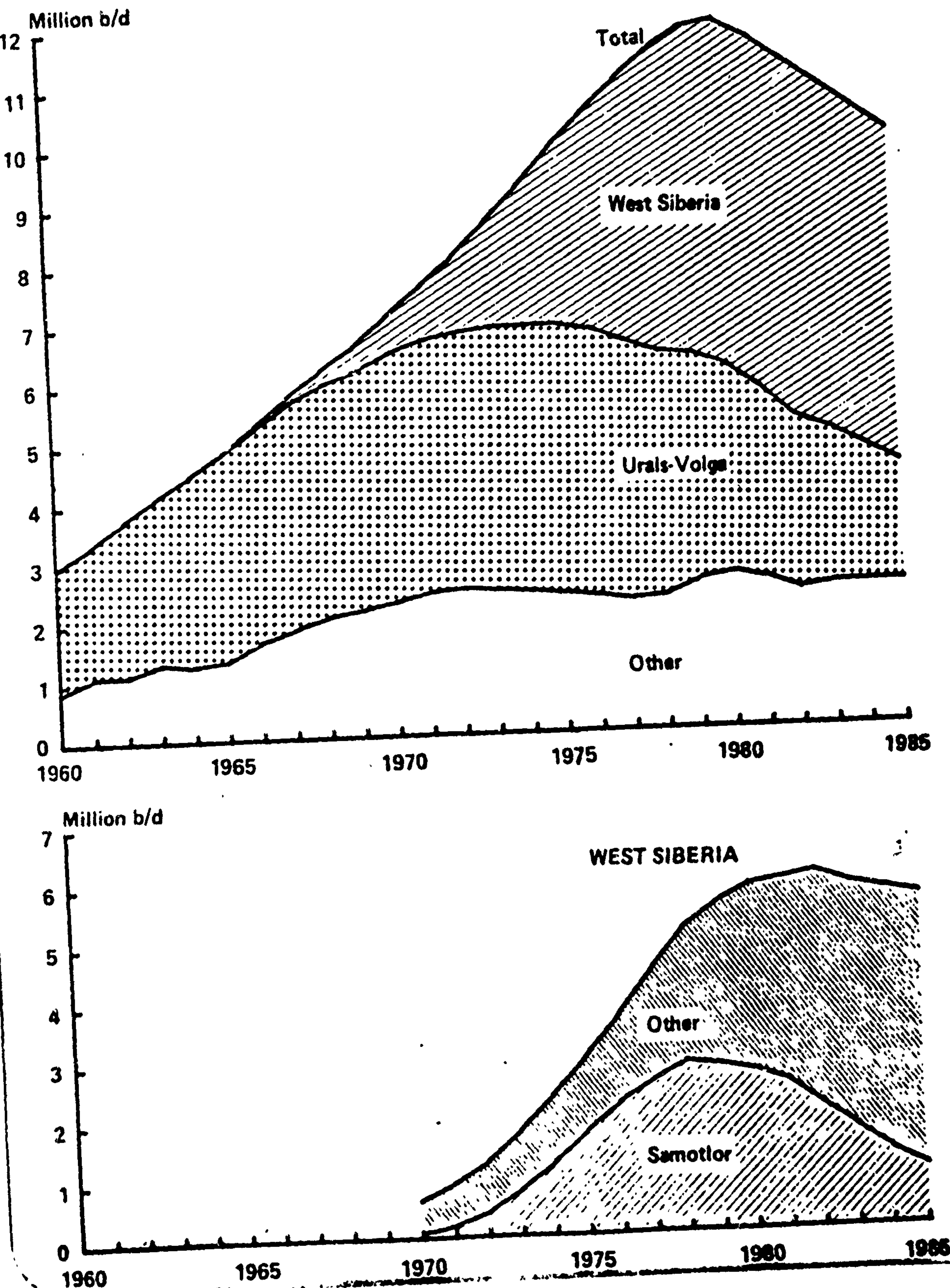
USSR: Primary Energy Production

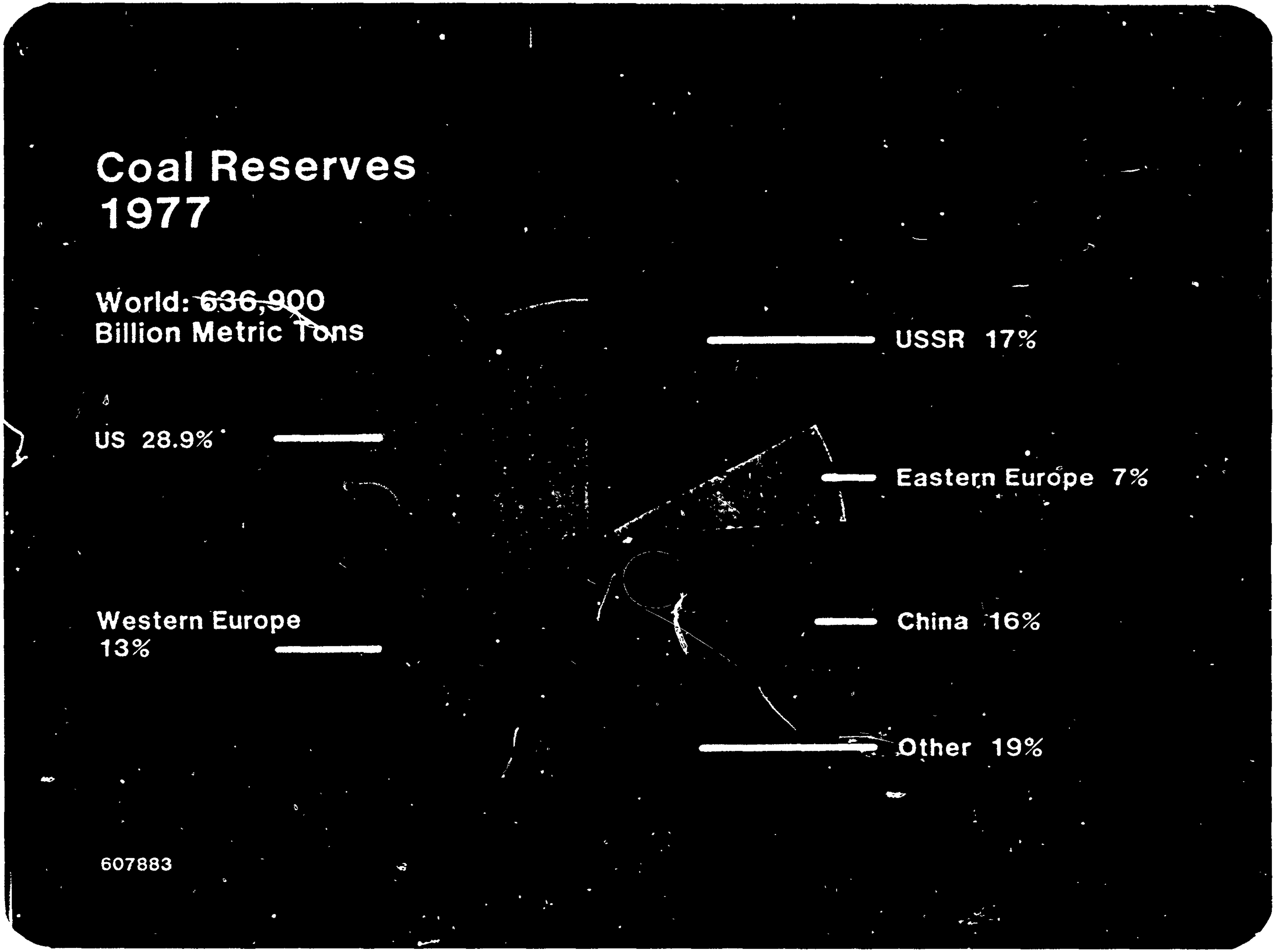



USSR
TERRAIN AND TRANSPORTATION
Coal
Oil and Gas Regions
Oilfields
Gasfields

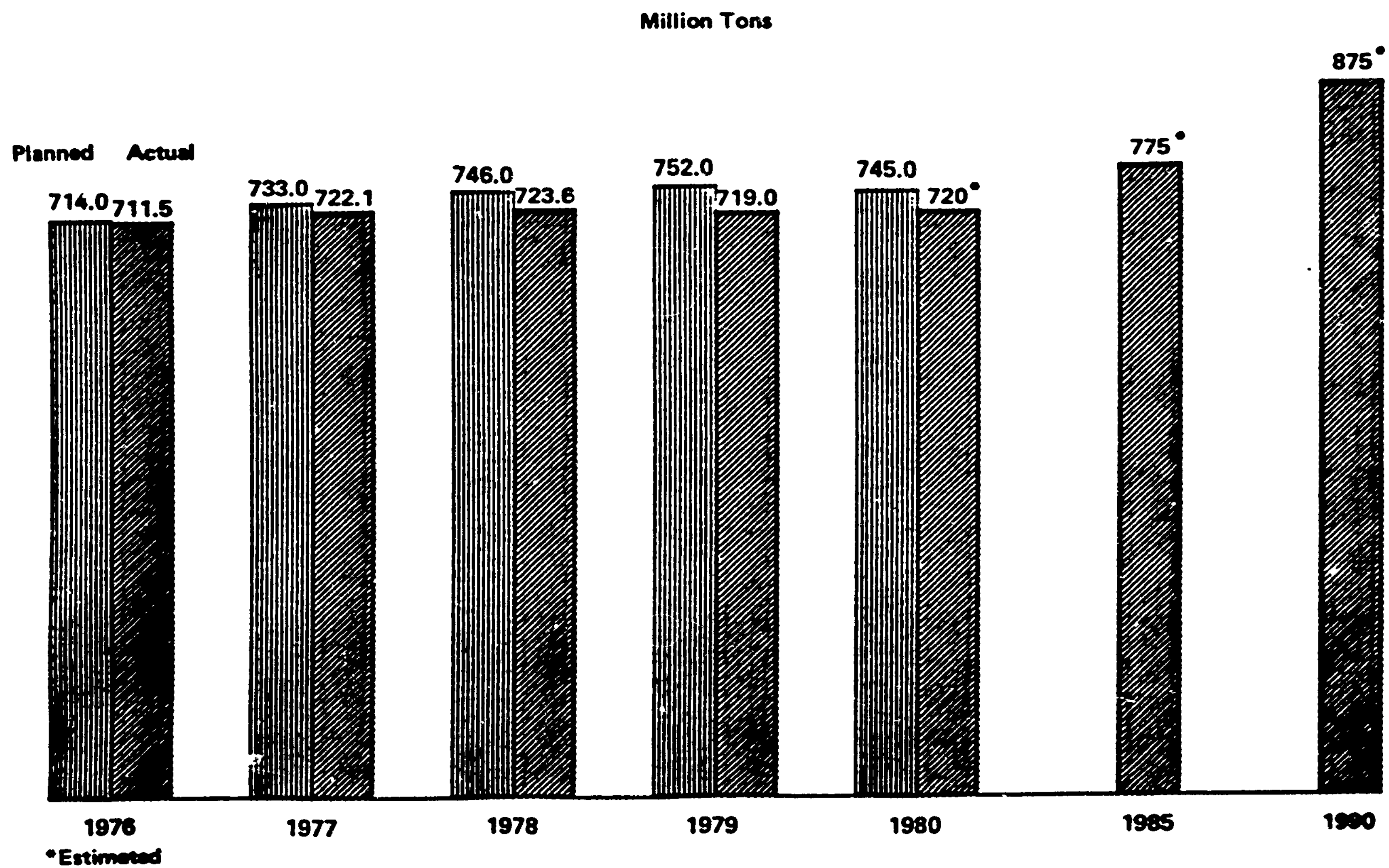
Figure 4

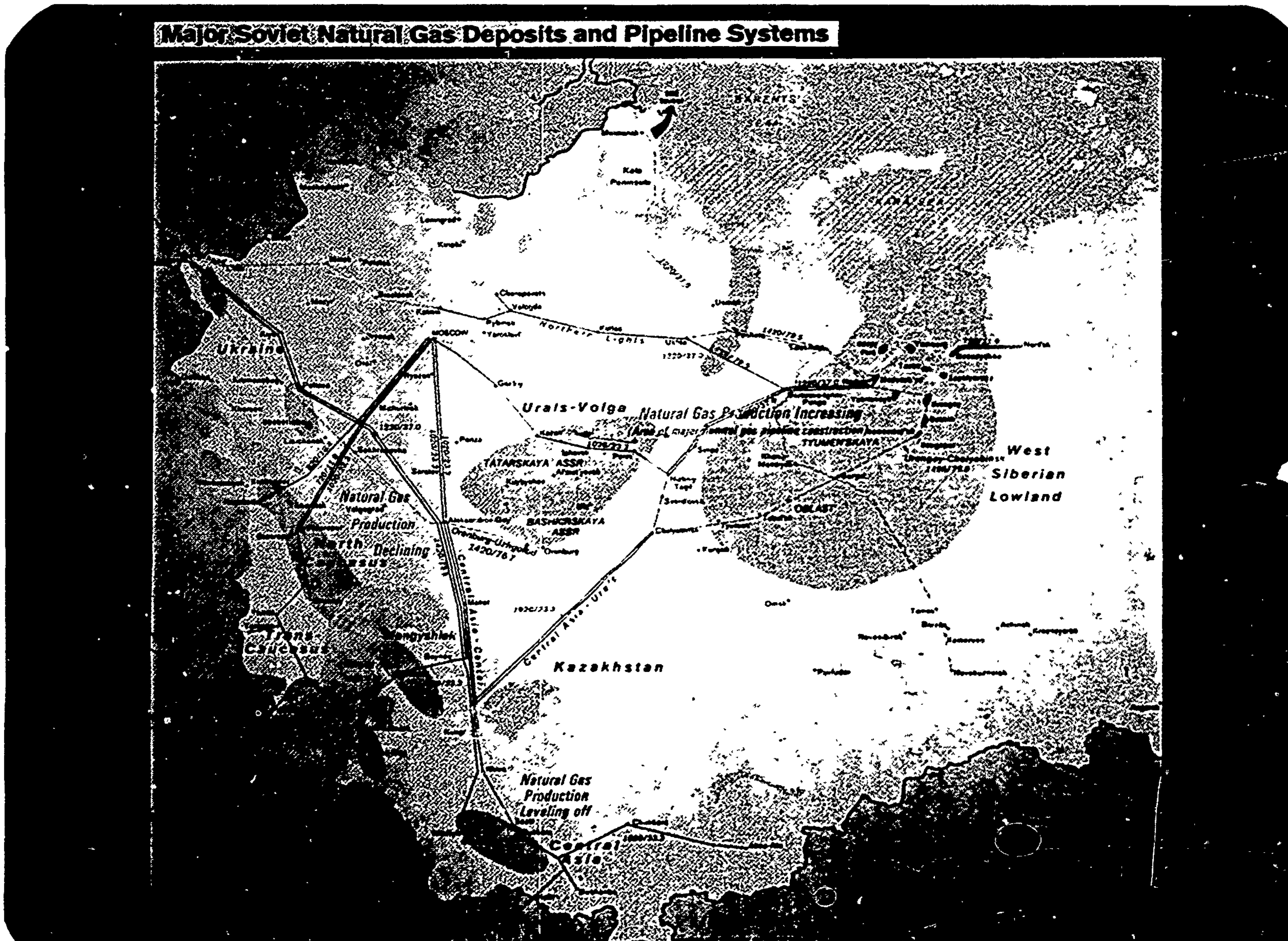
USSR: Regional Oil Production

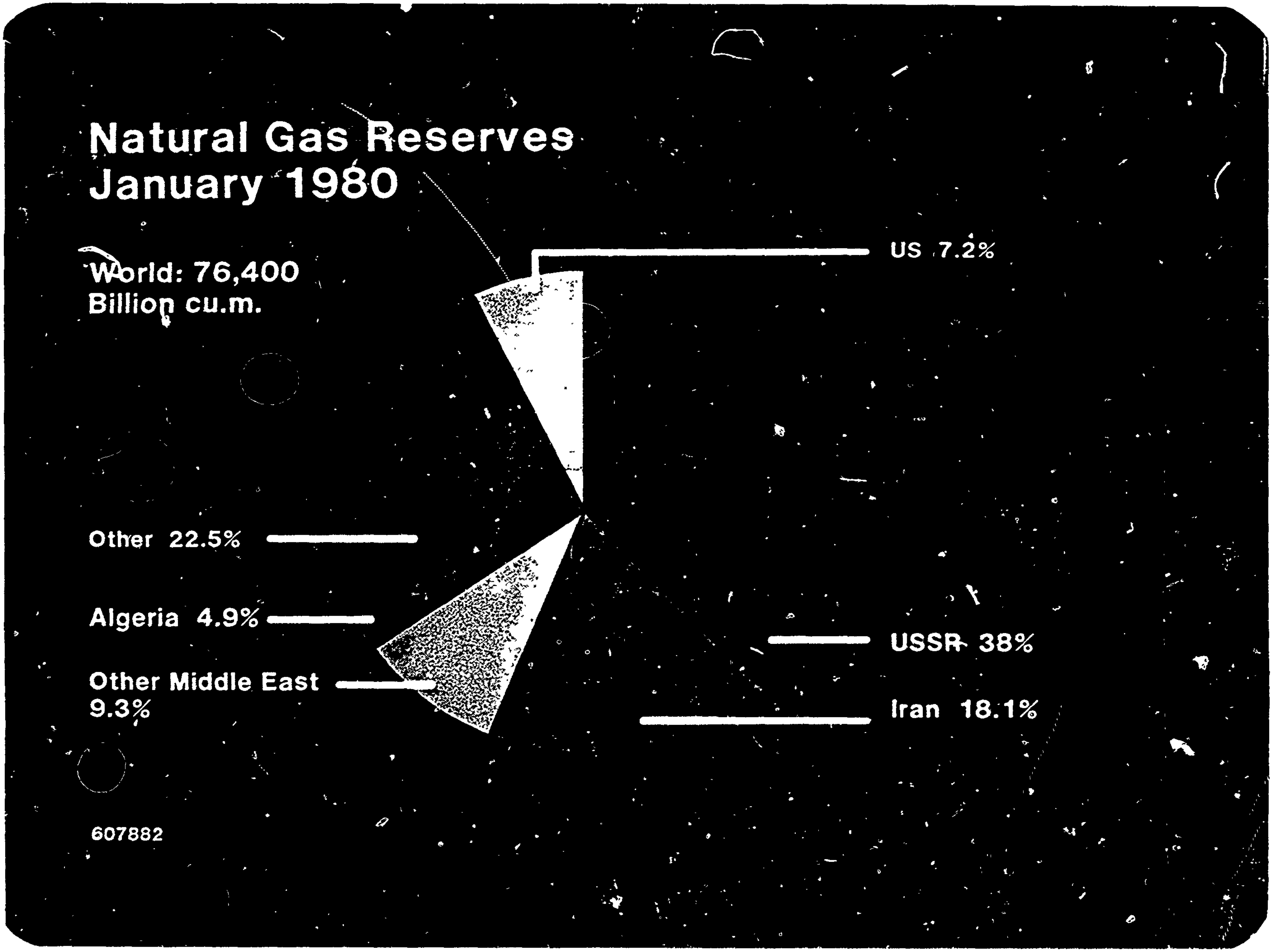


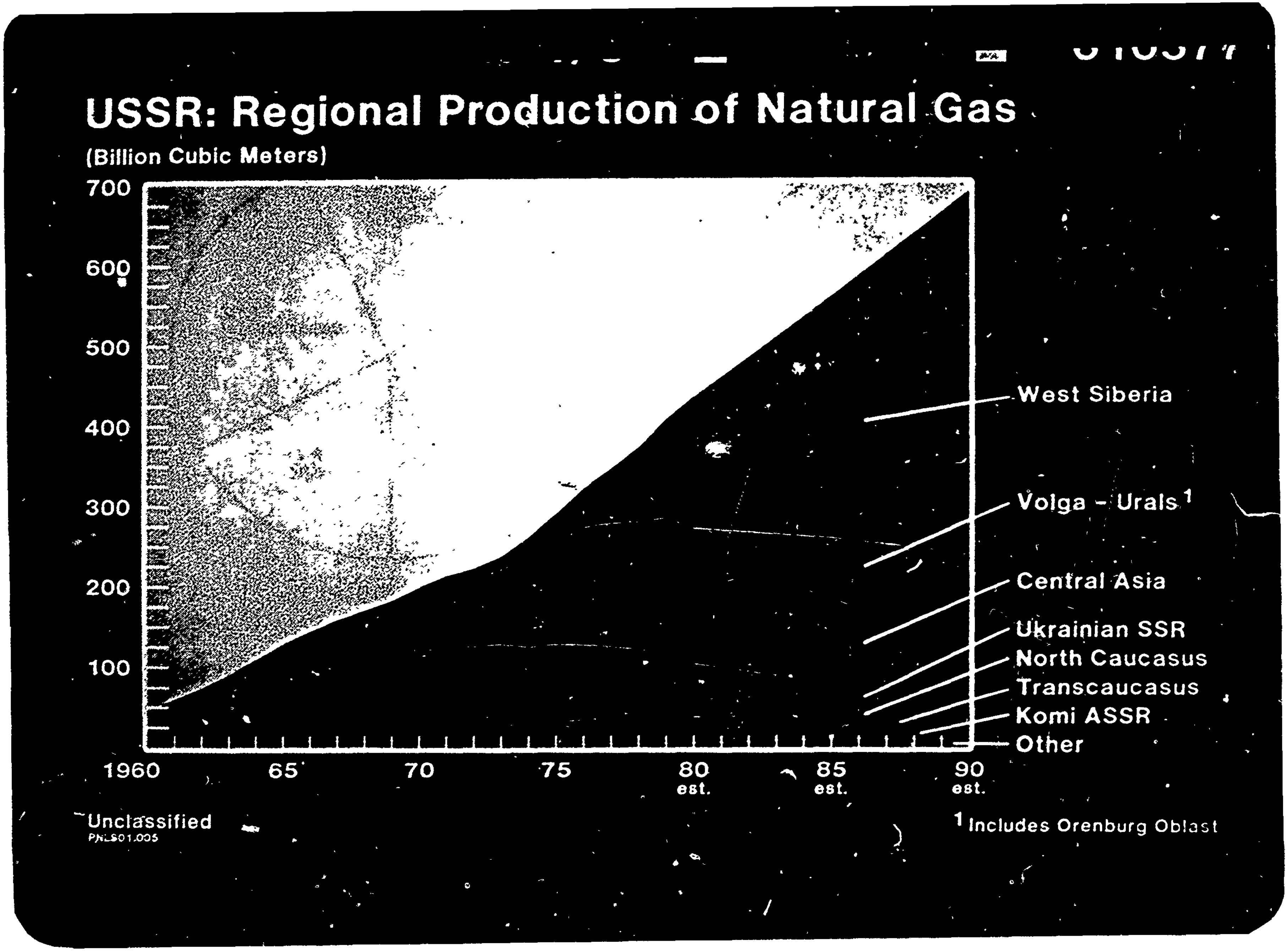

Coal Reserves
1977
World: 636,900
Billion Metric Tons
US 28.9%
Western Europe
13%
USSR 17%
Eastern Europe 7%
China 16%
Other 19%
607883

USSR: Raw Coal Production



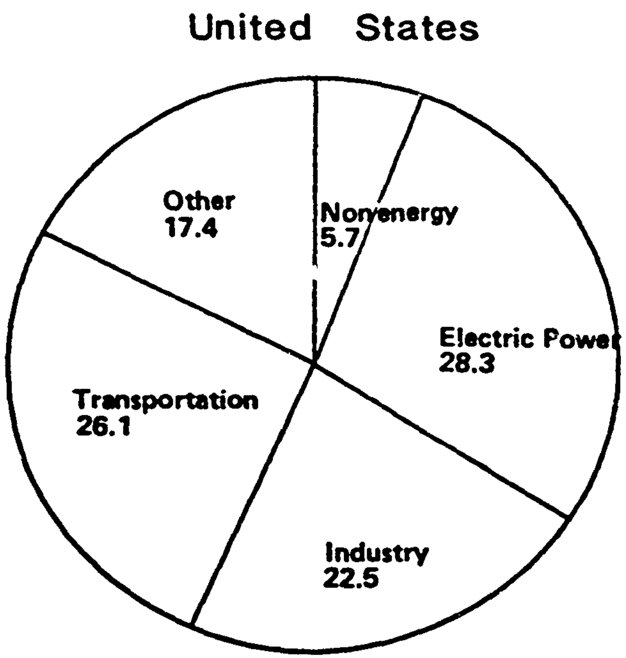

Major Soviet Natural Gas Deposits and Pipeline Systems
Ukraine
Moscow
Northern Lights
Urals-Volga
Natural Gas Production Increasing
TATARSKAYA ASSR
BASHKIRSKAYA ASSR
TYUMENSKAYA
OBLAST
West
Siberian
Lowland
Natural Gas
Production
Declining
North
Caucasus
Trans
Caucasus
Central Asia-Ural
Central Asia-Center
Kazakhstan
Natural Gas
Production
Leveling off
Central
Asia

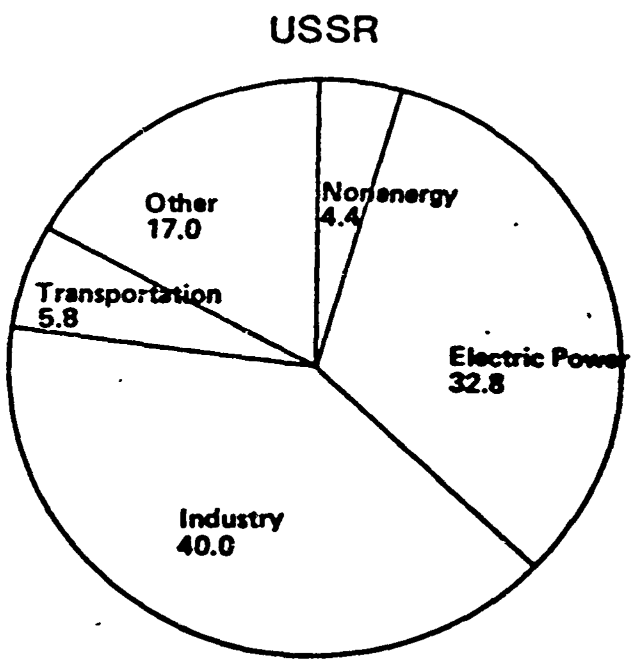

Natural Gas Reserves
January 1980
World: 76,400
Billion cu.m.
US 7.2%
Other 22.5%
Algeria 4.9%
Other Middle East
9.3%
USSR 38%
Iran 18.1%
607882


USSR: Regional Production of Natural Gas
(Billion Cubic Meters)
700
600
500
400
300
200
100
1960
65
70
75
80 est.
85 est.
90 est.
West Siberia
Volga - Urals 1
Central Asia
Ukrainian SSR
North Caucasus
Transcaucasus
Komi ASSR
Other
Unclassified
1 Includes Orenburg Oblast

United States and USSR: Gross Energy Consumption, 1975

Percent





Jet Fuel Trends in the U.S.

By K. H. Strauss

Research, Environment and Safety Department

Texaco Inc.

For presentation at

U.S. Air Force 1980 Energy Symposium

San Antonio, Texas

October 21-23, 1980

Jet Fuel Trends in the U.S.

By K. H. Strauss

To predict the possible future trends of jet fuel quality it is desirable to first study various aspects of present-day jet fuels, including methods of manufacture, fuel characteristics and availability. The same topics can then be used to discuss future fuels. This paper emphasizes kerosine-type jet fuels, but many of the comments apply to wider boiling-range fuels such as JP-4.

Present Jet Fuels

Current manufacturing methods are summarized in Table I. Most jet fuel is distilled directly from crude petroleum ("straight-run" fuel) and requires mercaptan removal by hydrogenation or conversion to disulfides by one of the listed chemical processes. Where necessary, total sulfur is reduced to acceptable limits by hydrogen treating and in a few refineries aromatics may be saturated by heavy hydrotreating. Jet fuel is also made by hydrocracking in processes where heavier molecules are cracked to kerosine-boiling range material but dehydrogenation is avoided by the addition of hydrogen in the process. With the exception of hydro-cracking jet fuel processing is relatively simple and fuel characteristics are established by crude selection and adjustment of the distillation range.

Table II illustrates the differences in the important properties of the kerosine-boiling fraction of five (None of these values are necessarily representative of finished jet fuel because in actual practice the distillation ranges would be adjusted for fuel optimization while the distillation ranges in the table are fixed for direct comparison.) The table also illustrates that some kerosines are of such a low quality (Crude C) that they would most likely not be used for jet fuel manufacture. After a crude is selected the fuel boiling range can be adjusted by varying the initial boling point, the final boiling point or both. Availability is increased by lowering the inital boiling point, raising the end point or both. As listed in Table III lowering the initial boiling point affects a number of important properties and in a general way leads to better combustion quality and improved low temperature properties but poorer handling safety, particularly for kerosine-type jet fuels. Increasing the end point or final boiling point, per Table IV, tends to result in lower combustion quality, poorer low temperature properties and little effect on handling safety. The reduced gravimetric heat of combustion may also become important for aircraft applications. Moving either the initial or final boiling point in the opposite direction produces the opposite effect from the one shown. However these particular changes decrease product availability.

Increasing availability through the adjustment of distillation ranges is limited by two major factors, existing specification

limits and competition for the same fraction by other products. Table V[a]* illustrates the interrelationship between kerosine flash point, freezing point and yield for two different crudes, providing no other constraints are considered. Thus for the paraffinic crude a simultaneous 11°C decrease in flash point and a 10°C increase in freezing point just about doubles the kerosine yield. The yield increase is almost as high for the naphthenic crude. Depending on the crude the increase would be less if another property such as smoke point or total aromatic content reaches its specification limit first. In actual fact, of course, there is also competition for the additional fuel. Kerosine is burned in lamps and heaters, although this use is tending to decrease in the U.S. A major demand for kerosine comes from No. 2 diesel fuel. An examination of the boiling ranges of No. 2 diesel versus kerosine reveals an extensive boiling range overlap, with the extent of overlap depending heavily on the low temperature characteristics of the diesel fuel. Unlike the jet fuel maximum freezing point, which is uniform across the U.S., the diesel fuel maximum cloud point is often varied between summer and winter and is further adjusted for climatic differences between locations. Because much of the kerosine is normally separated from the diesel fuel at the refinery much of the winter diesel fuel requires the addition of kerosine to be suitable for very cold weather operation. Figure 1 shows the large percentages of kerosine required to lower the cloud point of a particular No. 2 diesel. The non-linearity of the blending curve (curved solid line) is particularly noteworthy. The important point is that a given amount of kerosine is needed for a particular cloud point reduction whether this amount of kerosine is left in the No. 2 diesel fuel at the refinery or added in the field. No. 1 diesel fuel or No. 1 furnace oil is mostly kerosine plus some higher boiling straight-run material and therefore represents more direct competition with jet fuel for the kerosine fraction. However the volumes of these products are considerably less than those of the corresponding No. 2 fuels so that their overall effect is not as large as might otherwise be expected.

Jet Fuels of the Future

What will be the quality of future jet fuel? Much depends upon the time frame. Fuel changes in the next 5-10 years will be severely limited by the fuel requirements of existing aircraft and engines. This time period is simply a reflection of the development, approval and replacement cycle of new aircraft or engine parts. Beyond that time frame a number of deterrents act against drastically different fuels such as liquid hydrogen or liquid methane. The deterrents include long aircraft life, as well as high capital investment

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*Superscripts refer to references at the end of the paper.

costs for new aircraft, new airport fuel systems, new fuel distribution systems and new fuel manufacturing facilities. Oxygenated materials such as alcohols or ethers are inefficient as primary fuels and could pose significant compatibility problems if used as extenders. Here the virtual impossibility of "re-elastomering" an existing aircraft must be recognized. As a result only hydrocarbons are left as jet fuels for at least the next 25 years.

Canada is already using tar sands as a petroleum crude source and expects them to represent 40% of crude production by 1995. However the U.S. picture differs. Table VI[b] presents the sources from which the 1980 and 1990 total energy demand is likely to be met. Clearly coal is expected to absorb the largest increase, with oil demand (and supply) forecast to be practically constant. Table VII[b] breaks down the petroleum demand for the same period. Distillate, jet and "other" (largely petrochemical) fuel demand are expected to increase while motor gasoline and residual fuel volumes are predicted to decrease. The time period here is less important than the trend which augurs increasing distillate manufacture by residual fuel cracking as this fuel is replaced by coal. Catalytic crackers will be operated to produce less gasoline and more higher boiling fuels. At the same time another trend must be noted. Crude quality continues to decline in terms of increasing sulfur and aromatic content. In the longer term fuel from alternative sources will become more significant but at a slower rate than hoped for by some. Estimated ranges of such fuels for transportation use in the U.S. are shown in Table VIII. However a significant portion of these fuels are not considered suitable for jet fuel, either due to oxygen content or more likely their low hydrogen content if derived from coal. All these developments predict future jet fuel base stocks of significantly lower hydrogen content than today's fuels. In this connection Table IX outlines an important future problem, the drastic increase in hydrogen requirements for refinery processing. Only the first two processes are in general use today and refineries are already using most, if not all, of the inexpensive hydrogen generated by catalytic reformers during gasoline manufacture. The manufacture of process hydrogen for aromatic saturation or nitrogen removal, together with the need for high pressure hydrogenation facilities, will add significantly to the cost of future fuels and to energy losses during manufacture.

Again the competition for the same barrel is of concern. In addition to the uses already discussed a new demand may arise. At least one large automobile manufacturer[c,d] has voiced a requirement for a low aromatic, kerosine-boiling diesel fuel to help meet 1985 particulate limits for light duty vehicles. Table X puts this potential demand into focus. The year 2000 jet fuel demand was estimated by using the same growth rate per year as for the 1980-1990 period.

The diesel car demand assumes that car diesels will not be legislated out of existence but will represent 10% of new car sales in 1985 and 25% by the year 2000. Clearly such a diesel demand would seriously impact jet fuel avails toward the end of this century. Other demands, less clearly defined, can also be expected to intensify due to the relative decrease in crude avails.

Where do these projections lead? If the above events take place in an orderly manner they emphasize the importance of the NASA - Air Force trade-off studies which are discussed by other speakers. The trade-offs are sketched in Figure 2. There is undoubtedly a direct relationship between fuel quality and cost while the inverse is true for fuel quality and aircraft engine costs. Developing these matrices is not simple, particularly when energy balances must also be considered, but it should be done. Above all, however, I believe that fuel flexibility must be maintained in the transport and military aircraft systems. Forecasting is not a science and worldly events seldom progress in an orderly fashion. Thus it would make matters extremely difficult during a supply upset if fuel specifications had little or no flexibility in order that engines would meet emission regulations or that aircraft meet unusual mission requirements.

I would also like to see an intensive investigation of a neglected research area, fuel safety. Table III clearly demonstrated that a decreased initial boiling point results in a fuel better in all areas except safety. However no studies are available to define the means required to overcome these safety problems and thereby permit the use of lower initial boiling point kerosines with an overall safety equivalent to today's kerosines. It makes at least as much sense to me to develop ways of using such fuels without compromising safety as it does to investigate ways of utilizing the heavier portions of the barrel which are inherently more difficult to burn. Here again trade-off studies are all important.

If there is a single message it is that the greatest fuel flexibility of aircraft systems is the best way of assuring enough jet fuel to meet the demand.

References

[a]"Effect of Flash Point Reduction on Jet Fuel Properties", W. G. Dukek and E. R. Wieland, ASTM Special Technical Publication 688, American Society for Testing and Materials, Philadelphia, PA, December 1977.

[b]"Energy Perspectives in the 1980's", Finance and Economics Department, Texaco Inc, White Plains, New York, February 1980.

[c]"Prospects for Diesel Passinger Cars - and the Need for an Improved Fuel", D. L. Dimick, API Automotive and Industry Forum, American Petroleum Institute, January 23, 1980.

[d]"GM's Outlook on Future Automotive Fuels and Lubricants" J. M. Colucci, Preprint NO. 03-80, 45th Midyear Refining Meeting, Houston, Texas, American Petroleum Institute, May 13, 1980.

TABLE I

METHODS OF JET FUEL MANUFACTURE

- ATMOSPHERIC DISTILLATION
- MERCAPTAN REMOVAL
    - HYDROGEN TREATING
    - CHEMICAL CONVERSIONS
        - MEROX
        - DOCTOR
        - COPPER CHLORIDE
        - BENDER
- TOTAL SULFUR REDUCTION
    - HYDROGEN TREATING
- HYDROCRACKING
- AROMATIC SATURATION
    - HYDROGEN TREATING

TABLE II

KEROSINE QUALITY DEPENDS ON CRUDE SOURCE

CRUDE	A	B	C	D	E
KERO BOILING RANGE, °F	←		340-470		→
YIELD, %V	19.9	13.7	11.0	10.5	12.1
REL. DENSITY, 60/60°F	.7967	.8054	—	.7879	—
SULFUR, %	0.05	0.35	<0.05	0.04	0.03
SMOKE POINT	21.5	19.5	12	24	18.5
FREEZE POINT, °C	-47	-51	-37	-44	<-60

TABLE III

LOWERING INITIAL BOILING POINT

INCREASES	DECREASES
SMOKE POINT	DENSITY
HYDROGEN CONTENT	FLASH POINT
BTU PER POUND	AROMATIC CONTENT
VAPOR PRESSURE	NAPHTHALENES
	FREEZING POINT
	BTU PER GALLON
	VISCOSITY

AND LEADS TO

BETTER COMBUSTION QUALITY
BETTER LOW TEMPERATURE PROPERTIES
POORER HANDLING SAFETY
HIGHER GRAVIMETRIC HEAT CONTENT
LOWER VOLUMETRIC HEAT CONTENT

TABLE IV

RAISING FINAL BOILING POINT

INCREASES	DECREASES
DENSITY	SMOKE POINT
AROMATIC CONTENT	HYDROGEN CONTENT
NAPHTHALENES	BTU PER POUND
FREEZING POINT	
BTU PER GALLON	
VISCOSITY	

AND LEADS TO

LOWER COMBUSTION QUALITY
POORER LOW TEMPERATURE PROPERTIES
LOWER GRAVIMETRIC HEAT CONTENT
HIGHER VOLUMETRIC HEAT CONTENT

TABLE V

KEROSINE YIELDS *

PARAFFINIC CRUDE

FREEZING POINT	-50°C	-47°C	-40°C
FLASH POINT			
38°C (100°F)	10.0%	11.5%	15.0%
32°C (90°F)	12.3	13.8	17.5
27°C (80°F)	15.0	16.4	19.5
NAPHTHENIC CRUDE			
38°C (100°F)	18.2	21.0	27.5
32°C (90°F)	21.3	24.1	30.0
27°C (80°F	24.0	26.6	32.7

*FROM ASTM STP 688 (DUKEK — WIELAND)

TABLE VI

ENERGY DEMAND (USA)*

MILLIONS BARRELS/DAY OIL EQUIV.

	1980	1990
OIL	18.4	18.7
GAS	9.9	9.2
COAL	8.0	13.8
NUCLEAR	1.4	3.1
HYDRO	1.7	1.9
	39.4	46.7

*TEXACO (FEBRUARY 1980)

TABLE VII

PETROLEUM DEMAND (USA)*

MILLIONS OF BARRELS/DAY

	1980	1990
MOTOR GASOLINE	7.0	6.1
DISTILLATE FUEL	3.3	3.7
JET FUEL	1.1	1.4
RESIDUAL FUEL	2.7	2.5
OTHER	4.3	5.0
	18.4	18.7

*TEXACO, FEBRUARY 1980

TABLE VIII

U.S. TRANSPORTION FUELS FROM ALTERNATE SOURCES

YEAR	PERCENT OF FUELS
1980	LESS THAN 0.5
1990	4 - 7
2000	10 - 25

TABLE IX

HYDROGEN REQUIREMENTS

PURPOSE	HYDROGEN CONSUMPTION STANDARD $FT.^3$/BBL
MERCAPTAN REMOVAL	2 - 3
SULFUR REDUCTION	40 - 60
AROMATIC SATURATION (PETROLEUM LIQUIDS)	200 - 400
NITROGEN REMOVAL (SHALE)	250 - 300
AROMATIC SATURATION (COAL LIQUIDS)	500 - 800

TABLE X

COMPETITION FOR KEROSINE (USA)

MILLIONS OF BARRELS PER DAY

	1980	1990	2000
JET FUEL	1.1	1.4	1.8
AUTOMOTIVE DIESEL	~ 0.02	0.3	0.8

FIGURE 1

CLOUD POINTS OF KERO/DIESEL BLENDS

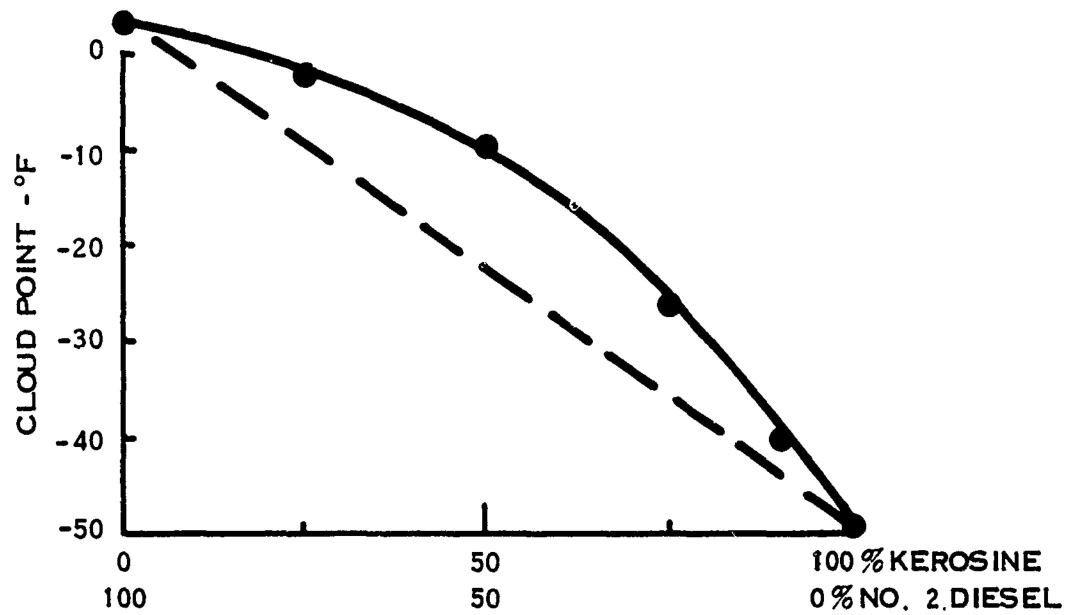
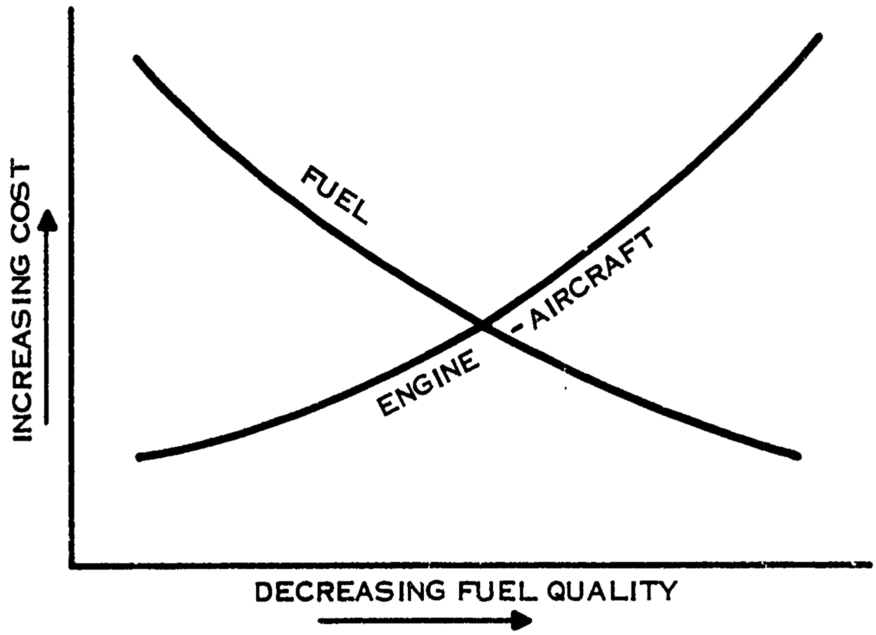


FIGURE 2

IMPORTANCE OF NASA/USAF ENGINE/FUEL STUDIES



"The Canadian Fuel Scene"

A Jet Fuel Supply Review

by

C.F. DeBoer

Imperial Oil Limited

Toronto, Ontario, Canada

Industry/Military Energy Symposium
San Antonio, Texas
October 21 - 23, 1980

The Canadian Fuel Scene

In Canada, like in the U.S.A., we, too, are concerned about a continued supply of jet fuel for the defence of North America and to keep the wings of civil aviation flying.

"In Canada the Future is Here Today"

What is meant by this seemingly contradictory statement will become clear later in this paper.

INTRODUCTION

The Canadian aviation turbo fuel supply scene is characterized by two distinctive factors.

First of all the Canadian market for gasoline and distillate is in a ratio of 1:1. This has been the case for many years and is forecast to gradually move to 0.6:1 by 2000. Many U.S. and Canadian refineries were designed with up to 1.7:1 ratios in mind. Thus most Canadian refineries operate near their maximum flexibility to produce distillates, requiring us to utilize considerable amounts of lower boiling naphtha fractions for the blending of wide-cut jet fuel in order to balance supply/demand.

Secondly, as synthetic crude production facilities are progressively phased in, Canadian refineries will see a steadily increasing aromaticity of certain feedstocks requiring careful scheduling of crude supplies to be able to operate within current jet fuel specification limits. This source of crude is expected to amount to 40% of Canadian crude production by 2000.

DISCUSSION

The use of Jet Fuel B is wide spread in Canada, not just by the military but by airlines and general aviation as well. As a matter of interest, helicopter operators prefer Jet B in the Northern parts of Canada due to its better low temperature flow properties and easier starting in the winter months. Consequently, Jet B is the Northern fuel with few exceptions.

TOTAL 1980 TURBO FUEL DEMAND IN CANADA

	MMB	% Of Total
TURBO FUEL A-1 (KEROSENE TYPE)	17.5	60
TURBO FUEL B (WIDE-CUT TYPE)	11.6	40

Figure 1

Figure 1 shows the vital importance of Jet Fuel B in the Canadian supply equation. This percentage is not expected to change much in the near term. This significant use of wide cut fuel frees up low pour material which is in perennial short supply especially during the winter months in Western Canada.

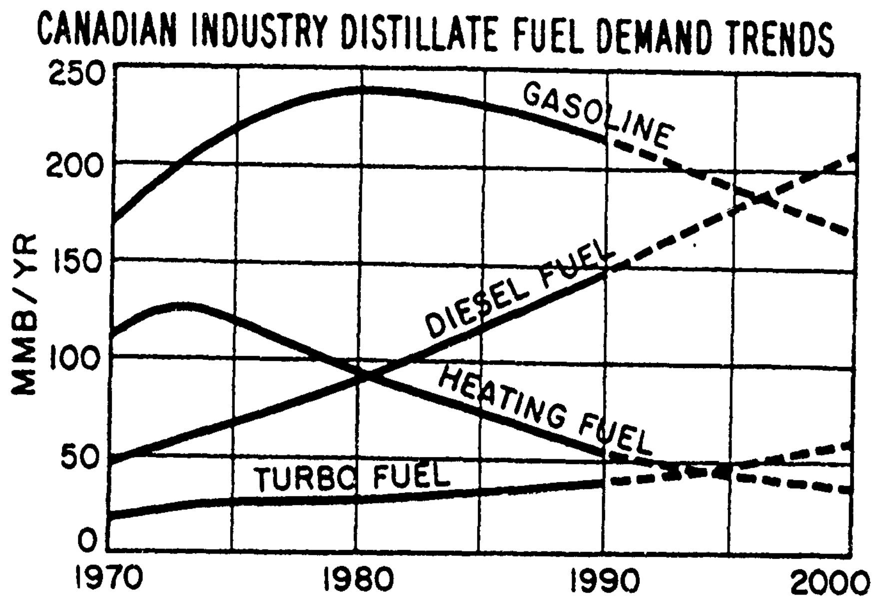


Figure 2

Returning to distillate fuel demands, Figure 2 gives the outlook for the Canadian demand trends for the 1980 to 2000 period. We foresee a levelling off of gasoline consumption and then essentially a declining demand for the forecasr period.

Heating oil demand is also declining as a resvlt of inroads made by natural gas and conservation measures. The two growth products are turbo fuel and diesel fuel. Diesel fuel

grows at a faster rate - nearly 5% per year and is due to increases in the trucking industry and increasing demand by passenger cars. Declining heating oil markets free up cracked gas oil which, although they contain large amounts of aromatic compounds, will likely be absorbed by the diesel fuel market. Jet fuel is expected to grow at an annual rate of approx. 4% Since the total Canadian demand for crude oil is forecast to actually remain essentially flat, it follows that pressure is being put on refineries to increase jet fuel yield.

Recent specification relaxations in freeze point, and flash point will provide some relief (Figure 3).

SIGNIFICANT SPECIFICATION LIMITS

CAN 2-323-M80 (JET FUEL-KEROSENE TYPE)

	JET A-1	JET A-2
FLASHPOINT °C	38 MIN.	33 MIN.
FREEZEPOINT °C	-47 MAX.	-47 MAX. NOV.-MARCH
		-45 MAX. APR.-OCT.
SMOKE POINT * mm	20 MIN.	20 MIN.
	REPORTABLE TO 18 mm	REPORTABLE TO 18 mm
AROMATICS % VOL	22 MAX.	22 MAX.
	REPORTABLE TO 25 MAX.	REPORTABLE TO 25 MAX.
LUMINOMETER	45 MIN.	45 MIN.
	REPORTABLE TO 40	REPORTABLE TO 40

* AT 3% MAX. NAPHTHALENES

Figure 3

The Jet A-1 freezepoint relaxation from -50°C to -47°C allows an increase in final boiling point for fuel produced from most conventional Canadian crudes. The establishment of Jet A-2 with a reduced flashpoint to 33°C from 38°C allows a lower initial boiling point. In addition, the A-2 specification provides for a seasonal freezepoint relaxation to -45°C. A C.G.S.B. task force is currently studying the possibility of a further seasonal freeze point relaxation based on Canadian climatic and flight operational data currently being collected. The combined effects of these modifications will result in an increase in potential supply of jet fuel. Although thus far no refinery has actually produced Jet A-2, its introduction is just a matter of time and will undoubtedly take place as supplies begin to tighten.

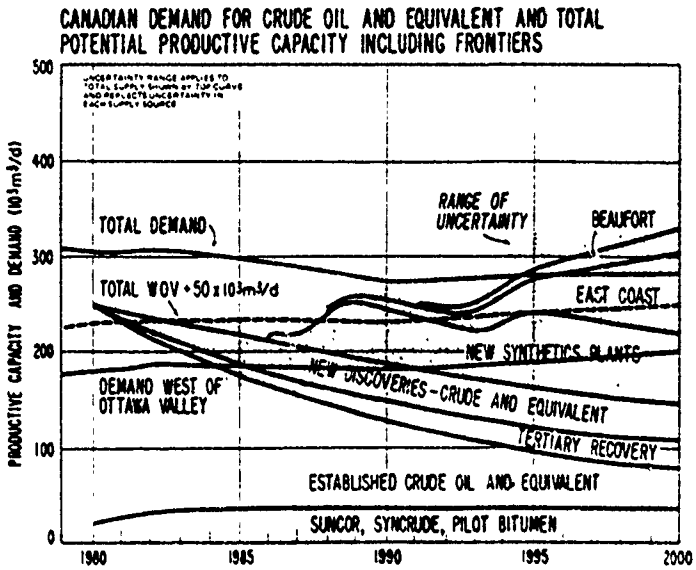


Figure 4

Figure 4 shows Canada's demand for crude oil between now and the year 2000. Current demand rate is 1.8 million barrels per day with imports from Venezuela, Mexico and other off-shore sources accounting for about 0.6 million barrels and the balance - 1.2 million barrels - produced in Canada. Our national goal is to become self-sufficient in the middle nineties. This of course is dependent on new sources coming on stream such as new synthetic plants, east coast off shore fields, arctic finds, etc. As mentioned earlier, the future is here today and selected refineries are already collectively processing some 185,000 barrels per day of synthetic crude oil. The National Energy Board forecasts that by 2000 about 40% of the total domestic production will come from non-conventional sources such as the Athabasca tarsands and other heavy oil deposits. Domestic conventional crude sources despite continuing discoveries will decline steadily in years to come.

TRANSPORTATION

The transport of crude oil to the main refining centres in Canada requires a vast network of pipelines.

The Interprovincial Pipeline transports crude all the way from Alberta to refineries as far away as Montreal, a trip of roughly three weeks! Product pipelines transport a variety of petroleum products with the Edmonton-Winnipeg leg being somewhat unique in that natural gas liquids and condensates are pumped through the same line as finished products such as

gasolines and jet fuels. This entails careful sequencing of batches to maintain present quality and avoid carry-over of trace contaminants.

NEW CRUDE SOURCES

As we indicated earlier, non-conventional crude sources such as heavy oils or bitumen are becoming increasingly important in filling Canadian demand for petroleum products.

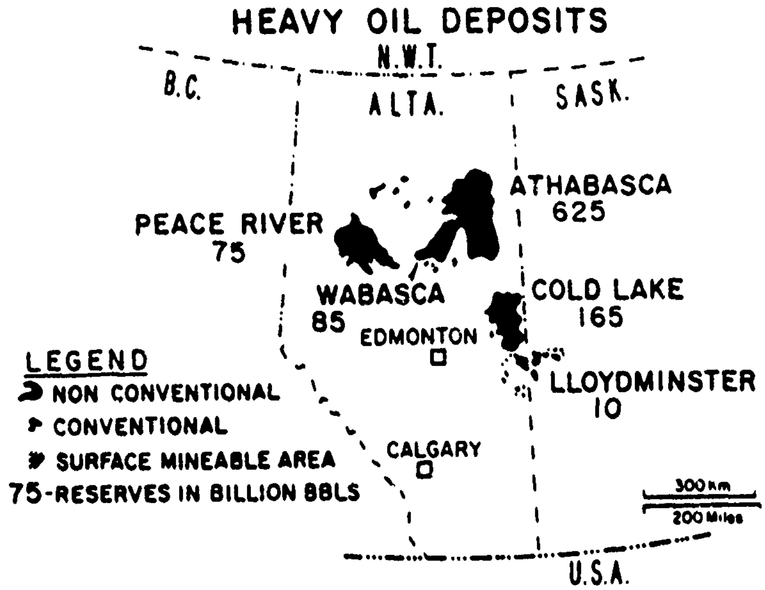


Figure 5

Figure 5 shows Canada with the heavy oil deposits indicated near Edmonton. It is evident that these fields are very large in area and resources they contain. The oil is found at depths from 0 to 2000 ft below the surface. The Athabasca Region contains the shallower deposits and surface mining is possible. The remainder of the Athabasca deposits and all heavy oils at the other locations have to be recovered using techniques termed "in-situ" recovery.

The Peace River deposit contains about 75 billion barrels of heavy oil in place. Next is Athabasca - the largest - with an estimated 625 billion barrels. Just to the South of it is Wabasca with about 85 billion barrels. Then comes Cold Lake with roughly 165 billion barrels.

HEAVY OIL DEPOSITS
BILLION BARRELS

	IN PLACE	RECOVERABLE
MINING	75	25
IN-SITU	875	90
	950	115

Figure 6

Figure 6 provides a summary of information on heavy oil resources in Alberta. As you can see only a small percentage of the heavy oil is considered to be recoverable at least at current prices and barring any dramatic technological breakthrough. The two existing heavy oil operations are both of the mining type. In-situ recovery is only being carried out at the pilot plants.

To give you an idea of the enormity of these operations, let's take a look at one of these mining plants - Syncrude. Its capacity is 125,000 bbls per day of synthetic crude. The construction costs were $2.2 billion and it employs around 3000 people.

SYNCRUDE RECOVERY PROCESS

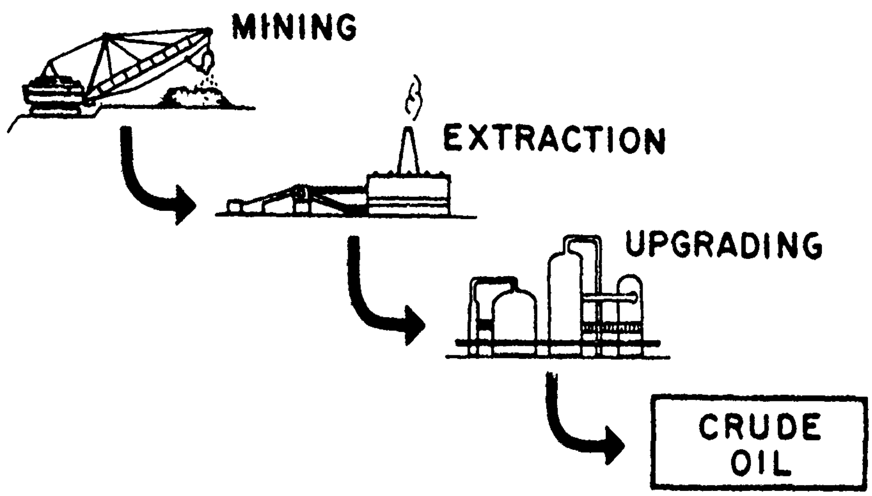


Figure 7

Figure 7 gives a simplified version of the production process.

The first step is to remove the overburden from 0 to about 50 feet. The bitumen is then mined to a depth of about 200 feet. Draglines with 80 cubic yard buckets excavate the exposed oil sands. A bucket wheel reclaimer picks up the windrowed long piles and through lump-separators passes the oil sands on to the conveyor system.

The output converges outside the processing plant where it is fed into production trains, mixed with steam and hot water in the tumblers and separated.

The aerated bitumen separates and floats as a froth.

Fluid cokers crack the oil to form coke, gas, naphtha and gas oil. The naphtha and gas oil are treated with hydrogen to remove sulphur and nitrogen and for stabilization, blended and shipped off as a synthetic crude to refineries. That is very briefly the Syncrude project.

An example of in-situ recovery is the proposed Cold Lake development. The challenge is to thin the bitumen, located at about 1500 feet below the surface, so it will move to the well bore to be pumped to the surface.

PROPOSED COLD LAKE PROJECT

OUTPUT

PER DAY .... 140,000 BARRELS

OVER 25 YEARS... 1.3 BILLION BARRELS

COST .... $ 7 BILLION

EMPLOYMENT

CONSTRUCTION..10,000

PERMANENT......2,000

Figure 8

Statistics (Figure 8) show the cost estimated at $7 billion by the time the project is completed in 1995.

COLD LAKE RECOVERY PROCESS

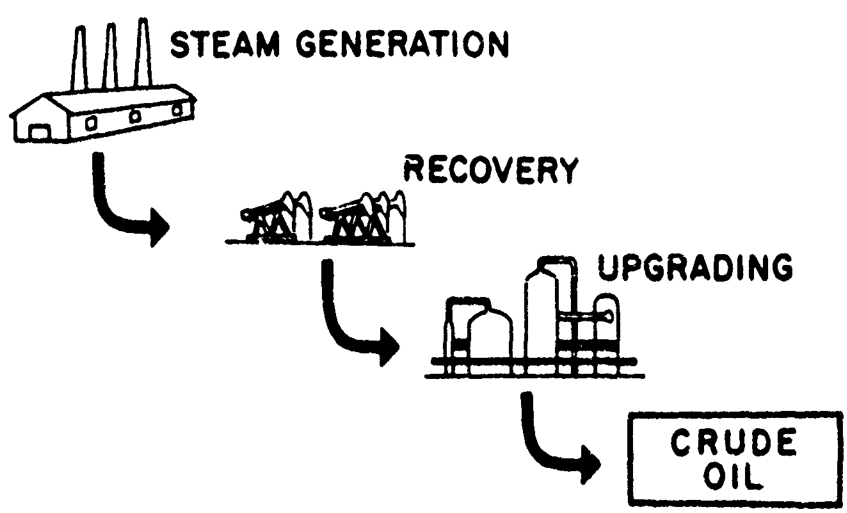


Figure 9

Figure 9 gives you an idea of the process that has been perfected to recover the heavy oil. Steam will be injected into 1400 wells which will be required initially to produce up to 141,000 barrels a day of upgraded oil.

EFFECT OF SYNTHETIC CRUDE ON TURBO FUEL QUALITY

Let's examine a typical analysis of a Turbo Fuel A-1 distillate from Western Canadian and Synthetic crudes by mass spectography (Figure 10).

COMPOSITIONAL ANALYSIS OF TURBO FUEL (WEIGHT %)

	Conventional	Synthetic
PARAFFINS	38.3	19.8
NAPHTHENES	41.0	44.6
ALKYLBENZENES	18.2	34.6
NAPHTHALENES	2.5	1.0

Figure 10

As can be seen the synthetic crude derived material contains a large amount of single ring aromatics limiting the blending of synthetic feedstock for refineries producing jet fuel to approximately 25% based on current reportable aromatics/smoke point limits. Refineries which have the ability to segregate jet fuel production from conventional crude only, can run higher volumes of synthetic crude and diesel fuel becomes the controlling product with its cetane number specification.

The quality of jet fuel produced from future synthetic crude plants will of course depend on the processing technology chosen for the upgrading of bitumen or heavy oil. But it is certain that relatively small changes in the jet fuel specifications such as an increase in aromatics percentage could have major implications on crude blending and processing flexibility in the future. See Figure 11.

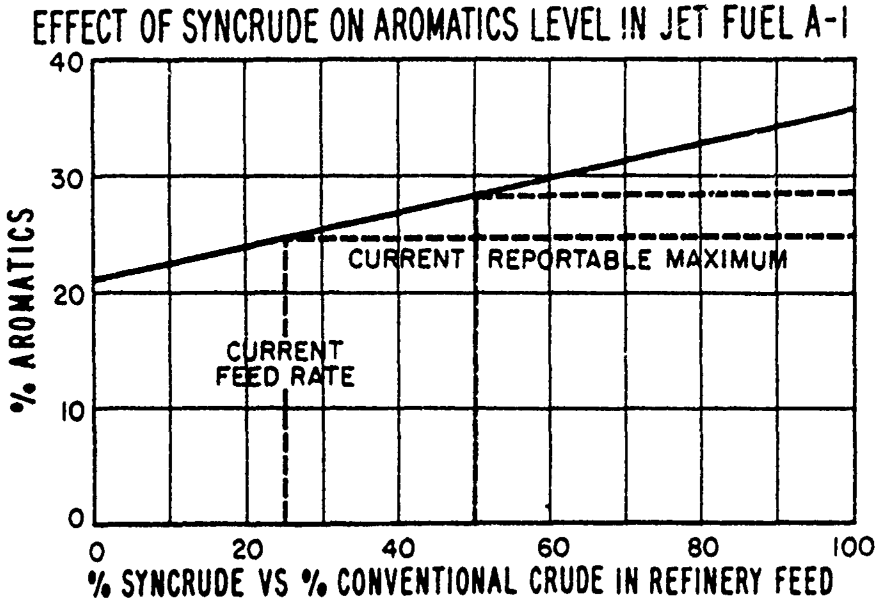


Figure 11

Inspections on a Turbo A-1 fractions refined from 100% synthetic crude are as follows (Figure 12):

PROPERTIES OF "JET FUEL A-1" PRODUCED FROM SYNTHETIC CRUDE

DISTILLATION RANGE °C	135-260
GRAVITY, °API	37.2
FREEZE POINT, °C	< -57
VISCOSITY, CST	
37.7°C	1.4
-34.4°C	8.2
AROMATICS % VOL	34
SULPHUR %	0.0024
SMOKE POINT mm	13.0
LUMINOMETER N°	32.8
NAPHTHALENES % WT.	0.8

Figure 12

Double ring aromatics (naphthalenes) content is well within acceptable range. Due to the absence of wax the freeze point is below -57°C. The aromatics content and smoke point are at unacceptable levels and as indicated earlier, is the reason why the use of synthetic crude is limited when refining jet fuels.

Hydrogen content is affected by aromatics level and the following table illustrates this clearly (Figure 13):

HYDROGEN CONTENT OF TURBO FUEL A-1

Conventional	Synthetic	H_2 Content (WT%)
100%	–	13.83
80%	20%	13.65
60%	40%	13.49
40%	60%	13.23
20%	80%	13.03
–	100%	12.90

Figure 13

The Vorbix and Double-Annular combustors, developed as part of the NASA Experimental Clean Combustion Programme, have shown that the maximum combustor liner temperature is insensitive to fuel hydrogen content.

Although these systems may or may not be applicable to future fuels from various sources, it illustrates that upgrading future fuels by means of costly and energy consuming processes to meet current hydrogen content levels should be considered carefully against developing engines that can accept "poorer" quality fuels.

Current cost comparisons indicate that a strong case may be made for the latter option.

SUMMARY

In summary, the Canadian jet fuel demand currently at 30 million barrels per year is expected to double over the next 20 years. By the year 2000 jet fuel will account for 9% of the crude barrel; an increase from 4-5% in 1980.

We plan to meet this demand by continuing to use wide-cut fuel giving the oil industry flexibility to re-assign low-pour material to diesel fuel and heating oil during the winter months. Full advantage will be taken of specification relaxations in freezing point and flash point of kerosene type fuel adding about 2% to crude run based on typical Western Canadian conventional crudes.

Many refinery feedstocks will become increasingly aromatic in nature pushing aromatic levels in jet fuel to current reportable limits. If synthetic crude plant come on stream as planned, jet fuel armoatics will limit refineries in their ability to process these crudes.

With engine combustion technology developments aimed at accommodating future crude sources, specifications realistically reflecting combustion parameters, government support and a little luck, we view the future with cautious optimism.

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1. Imperial Oil submission to the National Energy Board, Ottawa, 1980.

2. D.E. Steere and T.J. Nunn, "Diesel Fuel Quality Trends in Canada", SAE 790922. October 1, 1979.

3. Eldred N. Cart, Jr., "Comparison of Alternate Aviation Fuels", SAE 800767, May 20, 1980.

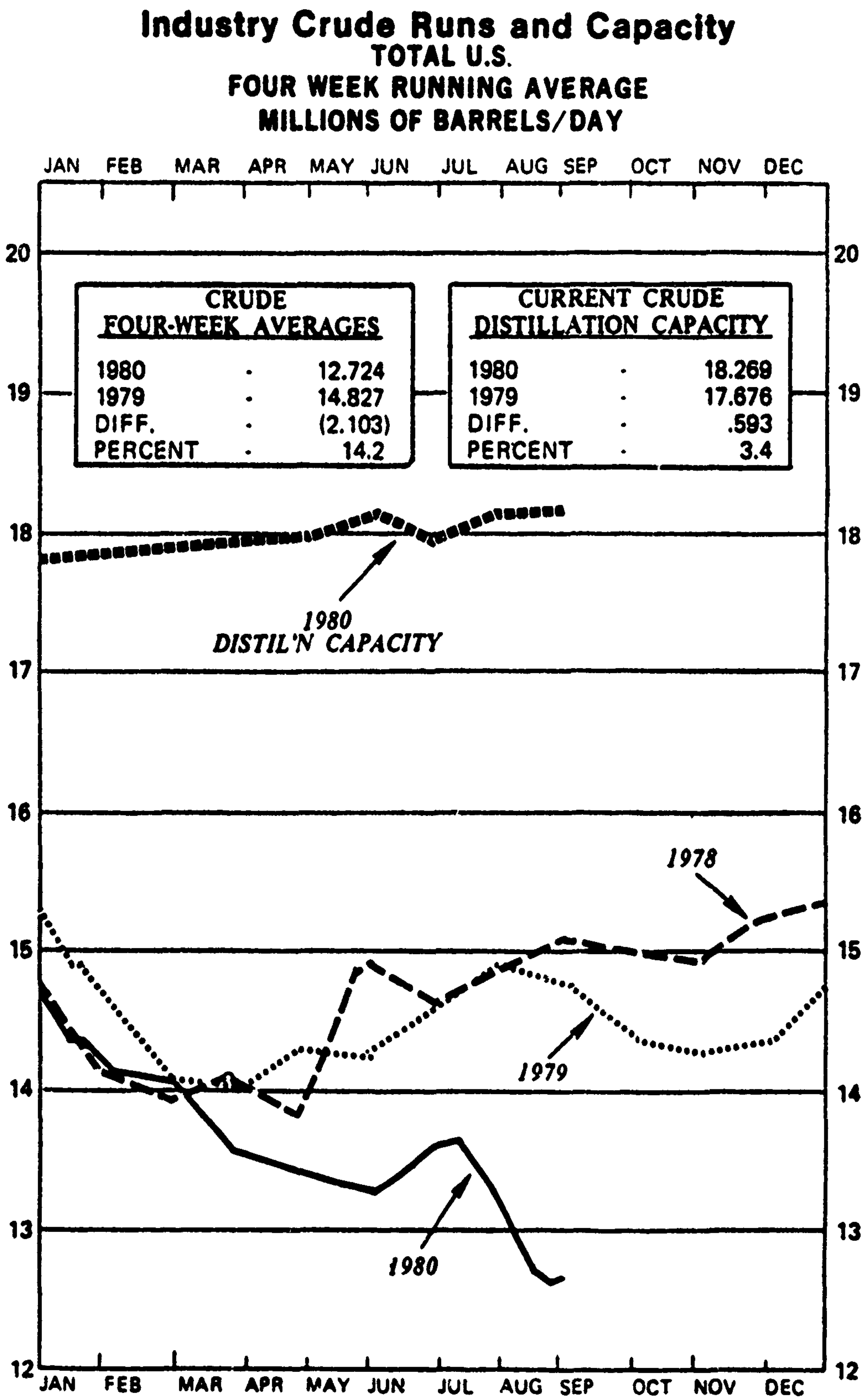
AIR FORCE ENERGY SYMPOSIUM

San Antonio, TX October 23, 1980

The attached material was presented by Mr. R. J. Linn - Director of Technological Development - American Airlines, to show the impact of fuel supply and price escalation impact on a major trunk carrier.

The charts describe price escalation history, effects of deregulation and fuel availability at new stations, and fuel efficiency trends of the American Airlines fleet.

FIGURE 1



Industry Crude Runs and Capacity
TOTAL U.S.
FOUR WEEK RUNNING AVERAGE
MILLIONS OF BARRELS/DAY
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
20
19
18
17
16
15
14
13
12
CRUDE
FOUR-WEEK AVERAGES
1980 · 12.724
1979 · 14.827
DIFF. · (2.103)
PERCENT · 14.2
CURRENT CRUDE
DISTILLATION CAPACITY
1980 · 18.269
1979 · 17.676
DIFF. · .593
PERCENT · 3.4
1980
DISTIL'N CAPACITY
1978
1979
1980

FIGURE 2

Industry Gasoline Stocks

TOTAL U.S.
MILLIONS OF BARRELS

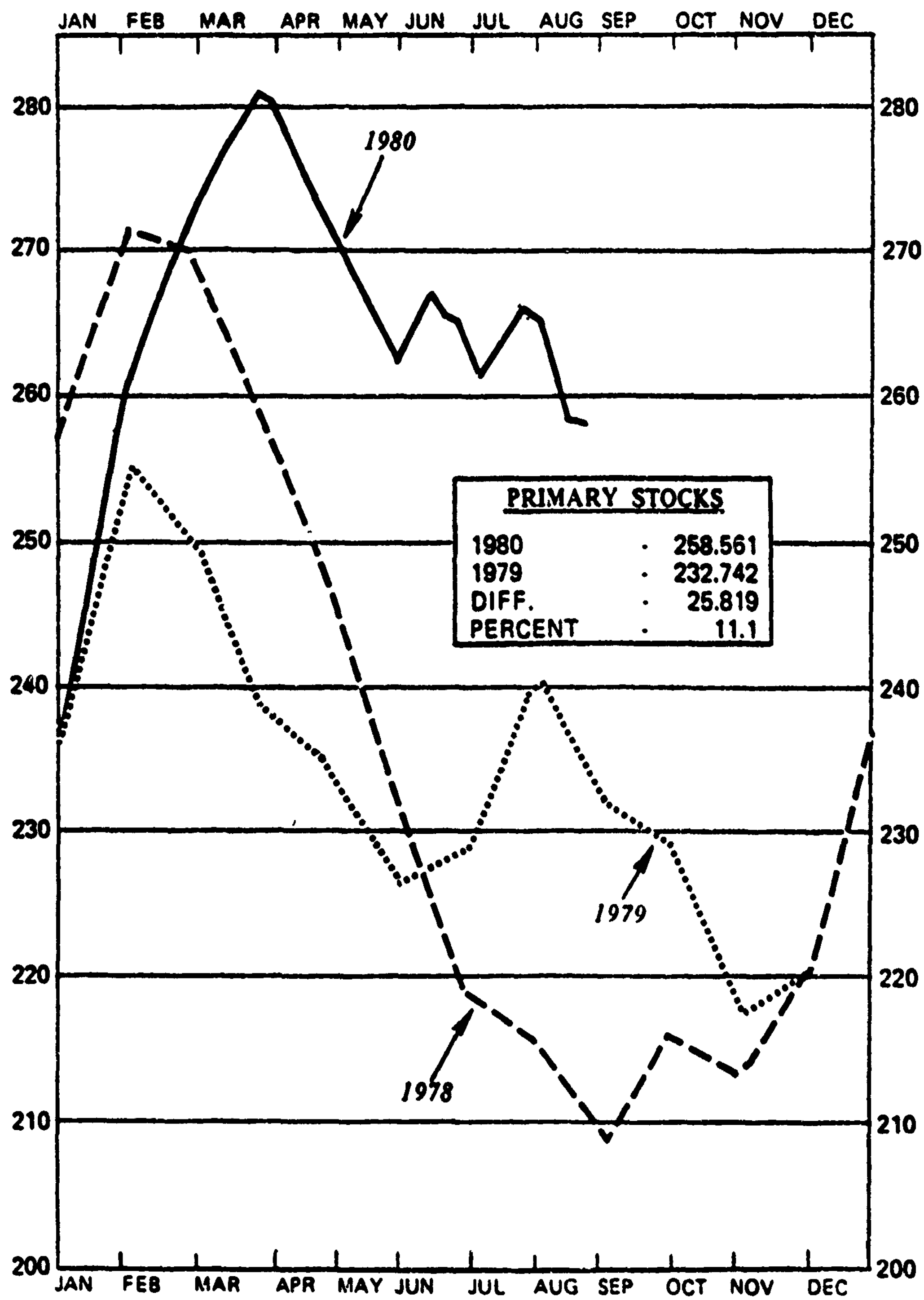


FIGURE 3

Industry Gasoline Demand - Total U.S.

FOUR WEEK RUNNING AVERAGE

MILLIONS OF BARRELS/DAY

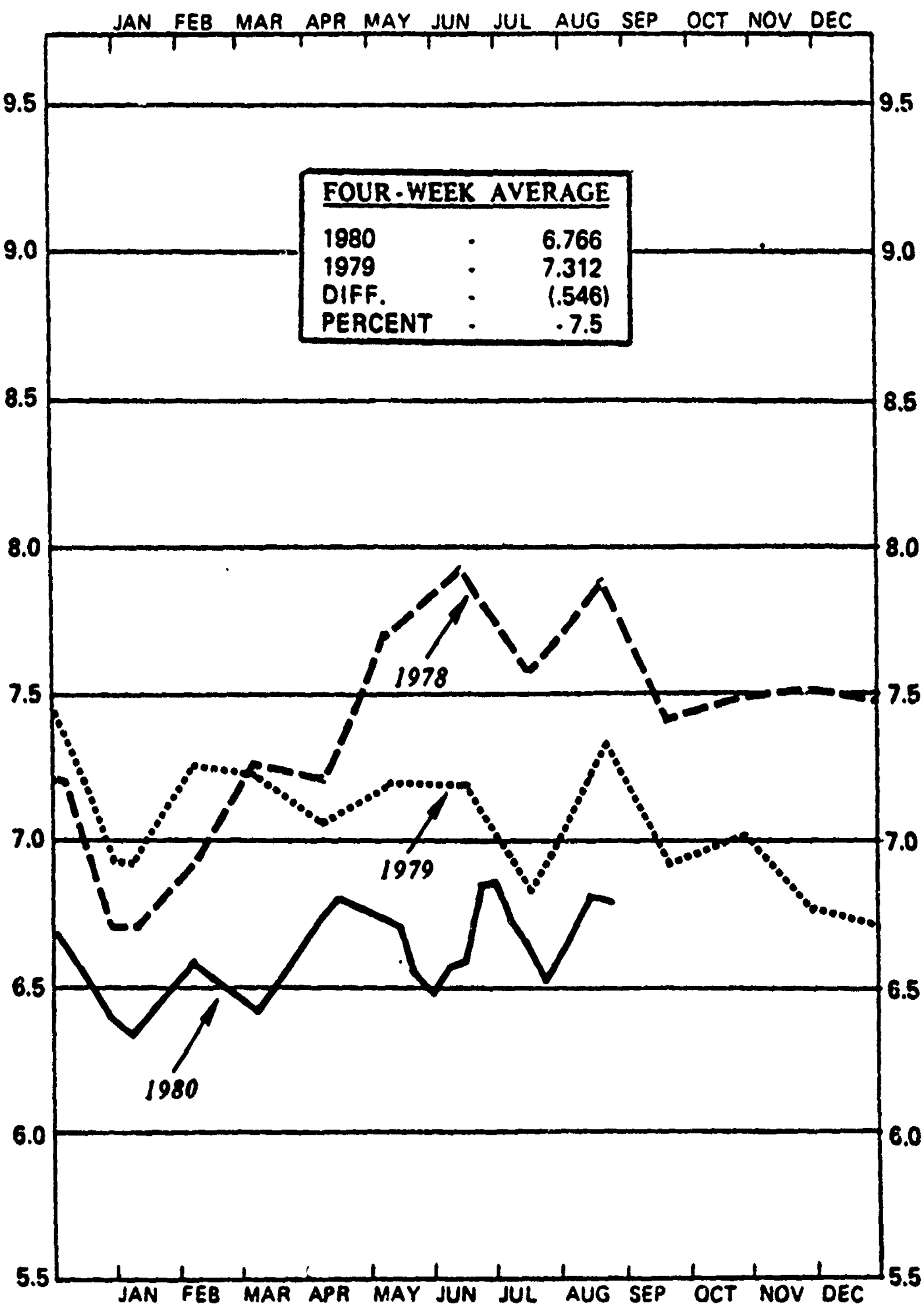


FIGURE 4

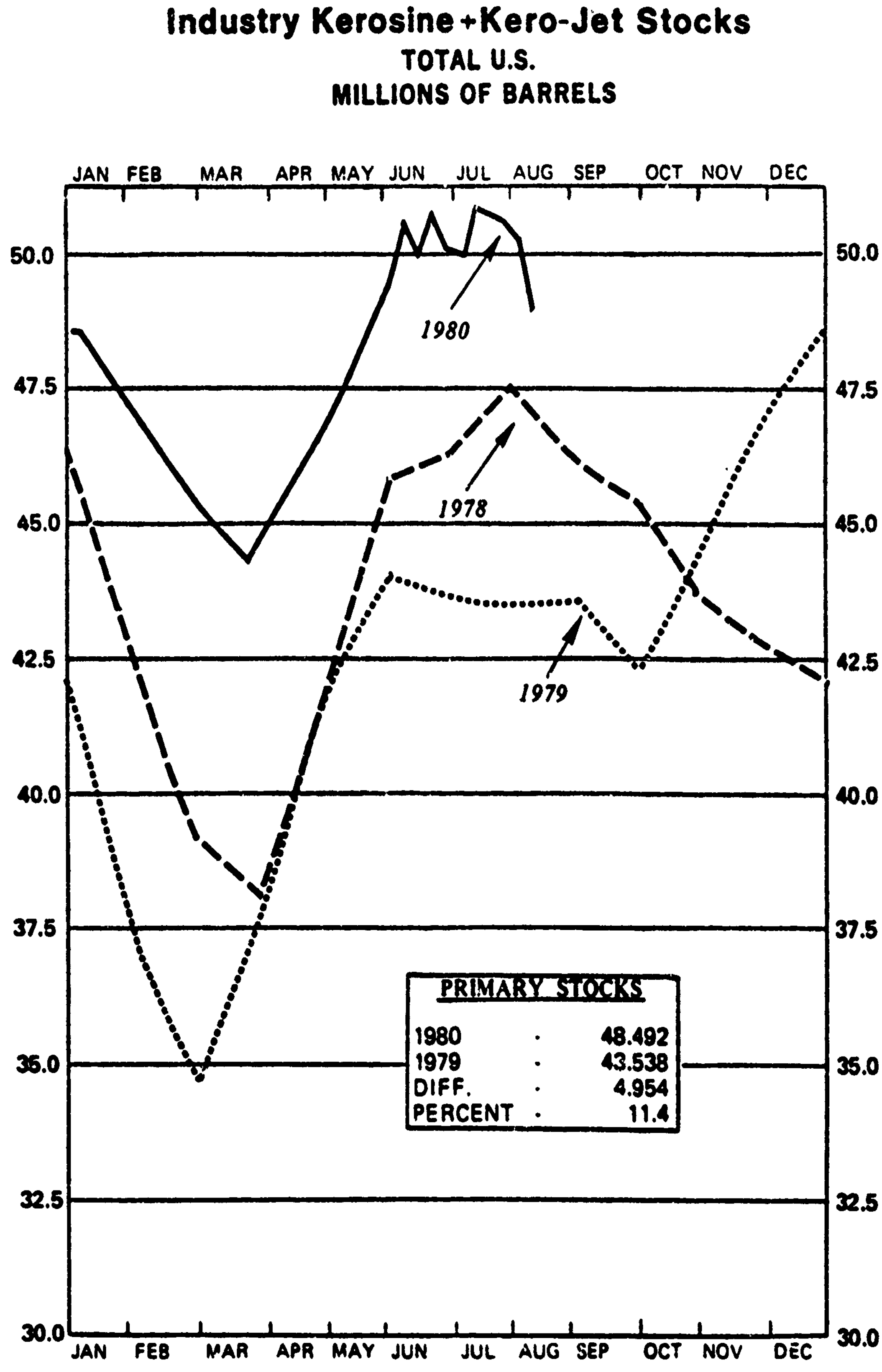

Industry Kerosine+Kero-Jet Stocks
TOTAL U.S.
MILLIONS OF BARRELS
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
50.0
47.5
45.0
42.5
40.0
37.5
35.0
32.5
30.0
1980
1978
1979
PRIMARY STOCKS
1980 · 48.492
1979 · 43.538
DIFF. · 4.954
PERCENT · 11.4

FIGURE 5

Industry Kerosene/Kero-Jet Demand

TOTAL U.S.
FOUR WEEK RUNNING AVERAGE
MILLIONS OF BARRELS/DAY

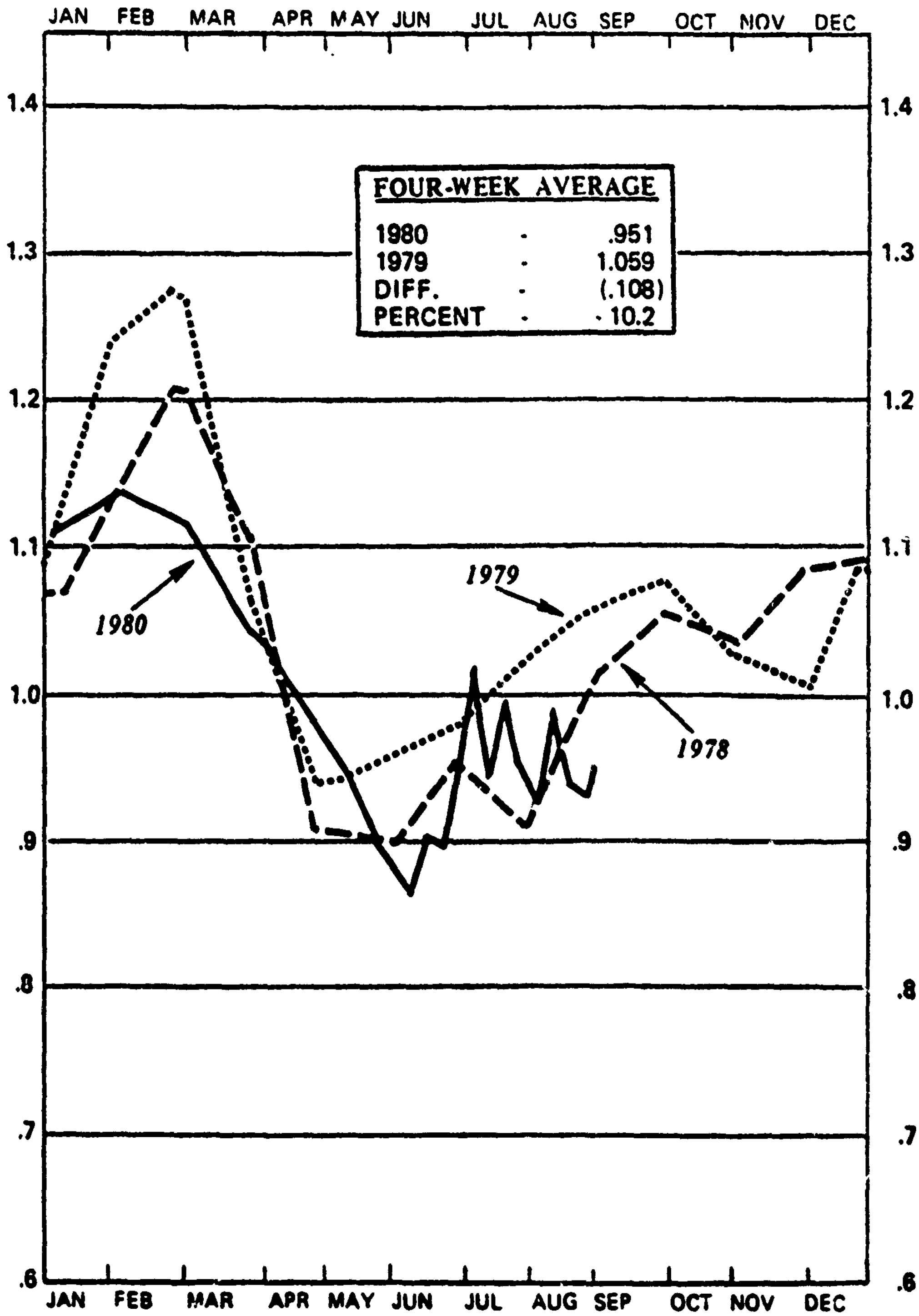


FIGURE 6

JET FUEL
SYSTEM USAGE/COST

	Gallons (000000)	Cost (000000)	Average Cost ¢/Gal.
1965	586	$ 56	9.6
1973	1,326	167	12.5
1974	1,139	242	21.2
1975	1,161	306	26.4
1976	1,212	325	27.0
1977	1,253	404	32.3
1978	1,286	503	39.2
1979	1,351	802	59.3
1980 (1)	1,240*	1,097**	88.5***

* 6.5% decrease under 1973
** 656.9% increase over 1973
*** 708.0% increase over 1973

(1) Eight mos. actual
Four mos. estimated

FIGURE 7

DOMESTIC TRUNKS DOMESTIC FUEL CONSUMPTION

Carrier	1976	1977	1978	1979
	Gallons (000)			
American	1,122,146	1,150,803	1,169,990	1,220,402
Braniff	329,017	357,210	405,609	485,521
Continental	292,878	337,106	367,798	380,022
Delta	904,688	956,337	1,050,046	1,109,257
Eastern	940,660	976,369	1,032,516	1,084,114
National	264,593	287,986	291,291	291,797
Northwest	469,627	482,608	289,179 (2)	450,024
Pan American	83,887	82,650	93,734	89,965
Trans World	849,484	867,886	844,439	853,913
United	1,478,725	1,541,079	1,630,499	1,285,570 (1)
Western	307,435	333,821	352,486	342,463
Total	7,043,140	7,373,855	7,527,587	7,593,048

(1) On strike March, April, and most of May
(2) On strike April 29 to August 15

FIGURE 8

DOMESTIC TRUNKS
Average Price
Per Gallon
1980

	Jan.	Feb.	Mar.	Apr. (1)	May	Jun.	Jul.	Aug.	Sep.	Oct.
American	80.649	86.653	89.333	89.666	91.552	90.482	90.524	88.949		
Braniff	79.256	84.011	84.728	86.835	89.123	89.581	88.931			
Continental	73.802	80.519	83.849	85.060	86.422	87.472	87.750			
Delta	75.260	80.696	84.647	84.876	85.853	86.961	87.880			
Eastern	77.076	81.932	84.992	85.255	85.218	87.395	86.710			
National (2)	76.801	81.939	85.133	85.778	86.080					
Northwest	80.741	86.413	88.892	89.601	89.372	90.544	90.958			
Pan American	70.824	76.494	80.509	80.758	81.112	85.963	87.292			
TWA	80.183	84.821	87.927	87.606	87.884	88.770	89.528	88.992		
United	72.314	78.906	82.194	82.768	83.918	85.898	87.400	88.400		
Western	79.051	84.072	89.047	86.113	86.689	87.271	90.201			
AVERAGE	76.863	82.457	85.540	85.875	86.766	87.861	88.496			

(1) Trans Border Canadian data transferred from International to Domestic. Jan, Feb, Mar reflects Trans Border Canadian data in International

(2) National data combined with Pan American effective June 1980

FIGURE 9

OFF-AIRPORT STORAGE

Location	Leased From	Capacity/Gals.
Carteret, N.J.	Gatx	12,600,000
East Chicago, Ind.	Cities Service Co.	24,360,000

FIGURE 10

SPOT FUEL PURCHASES AND COMMITMENTS

Month	1980 Gallons	1980 Cost
January	9,449,328	$ 8,959,683
February	5,257,686	4,893,629
March	- 0 -	- 0 -
April	8,401,386	6,949,021
May	2,100,000	1,745,625
June	1,037,610	883,421
July	4,159,000	3,451,140
August	14,667,669	12,086,250
Sub-Total	45,072,679	$38,968,769
Balance of Committed Spot Fuel To Be Delivered	42,792,000	36,892,449
TOTAL	87,864,679	$75,861,218

September 25, 1980

FIGURE 11

ALOHA - HONOLULU

Annual Turbine Fuel Requirements Estimated - 30,000,000 Gallons

Supply - 1) HNL Est. Annual Turbine Fuel Requirements - 14,000,000 Gallons

Tanker "Esso Bayonne" - docked during September, 1980 - 200,000 bbls. (8,400,000 gallons) in storage at HIRI, sufficient supply to handle current proposed schedule through June, 1981. Remainder in storage with our historic supplier on West Coast, Arco. Arrangements will be made as required to make this fuel available in HNL.

2) LAX Est. Annual Turbine Fuel Requirements - 16,000,000 Gallons

Total LAX turbine fuel requirements covered by contract with our historic West Coast supplier.

FIGURE 12

B-747

COST TO "FILL-ER UP"

Year	Volume (Gls)	Price (Cents/Gl)	Total Cost
1973	47,000	12.5	$ 5,875
1975	47,000	26.4	12,408
1977	47,000	32.3	15,181
1978	47,000	39.2	18,424
1979	47,000	59.3	27,871
1980 (Est)	47,000	88.5(1)	41,595
1985 (Est)	47,000	159.0	74,730

(1) 1980 Price = 8 mos. Actual + 4 mos. Fuel Budget

FIGURE 13

AMERICAN AIRLINES

FUEL EFFICIENCY TREND - PASSENGER FLEET

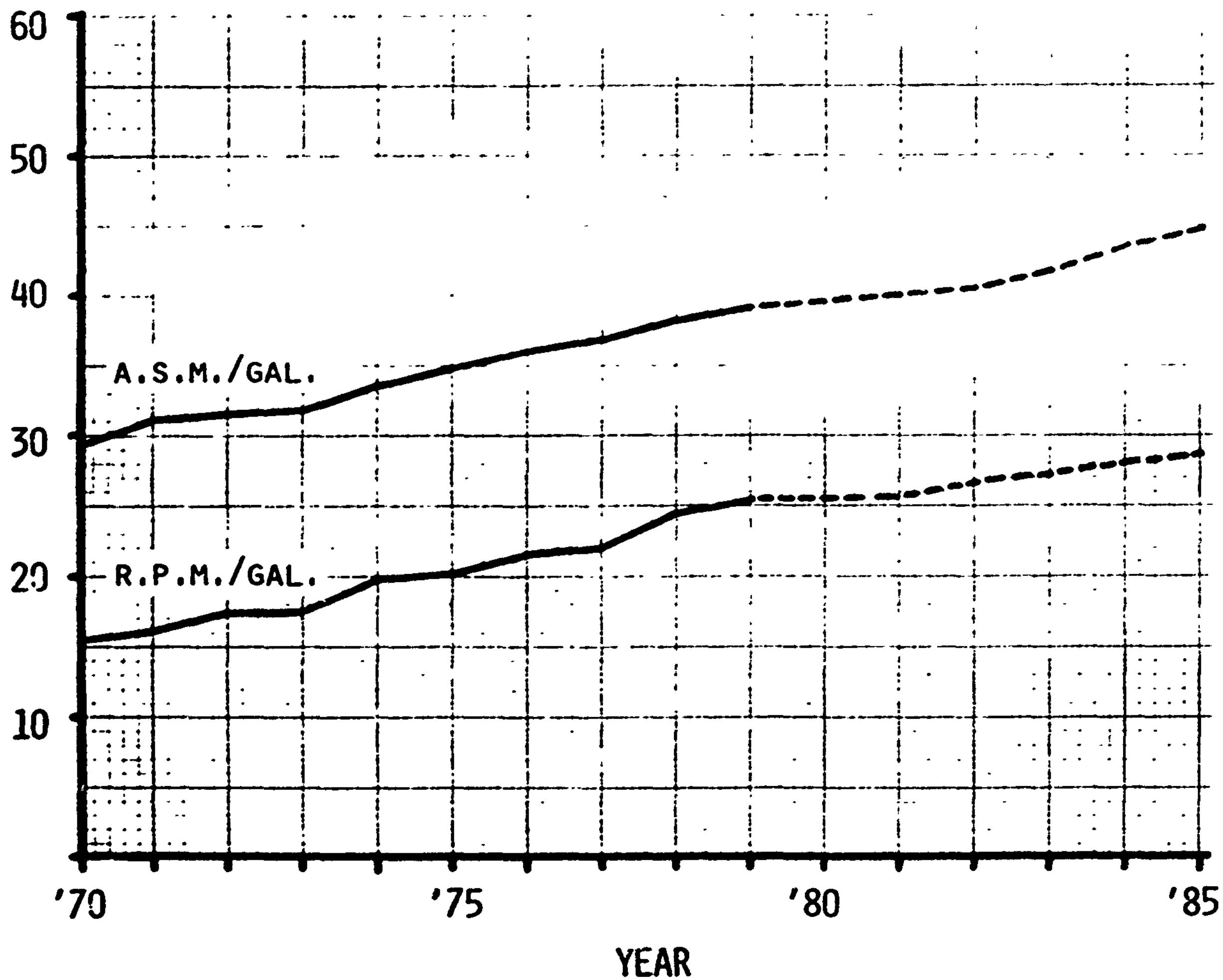
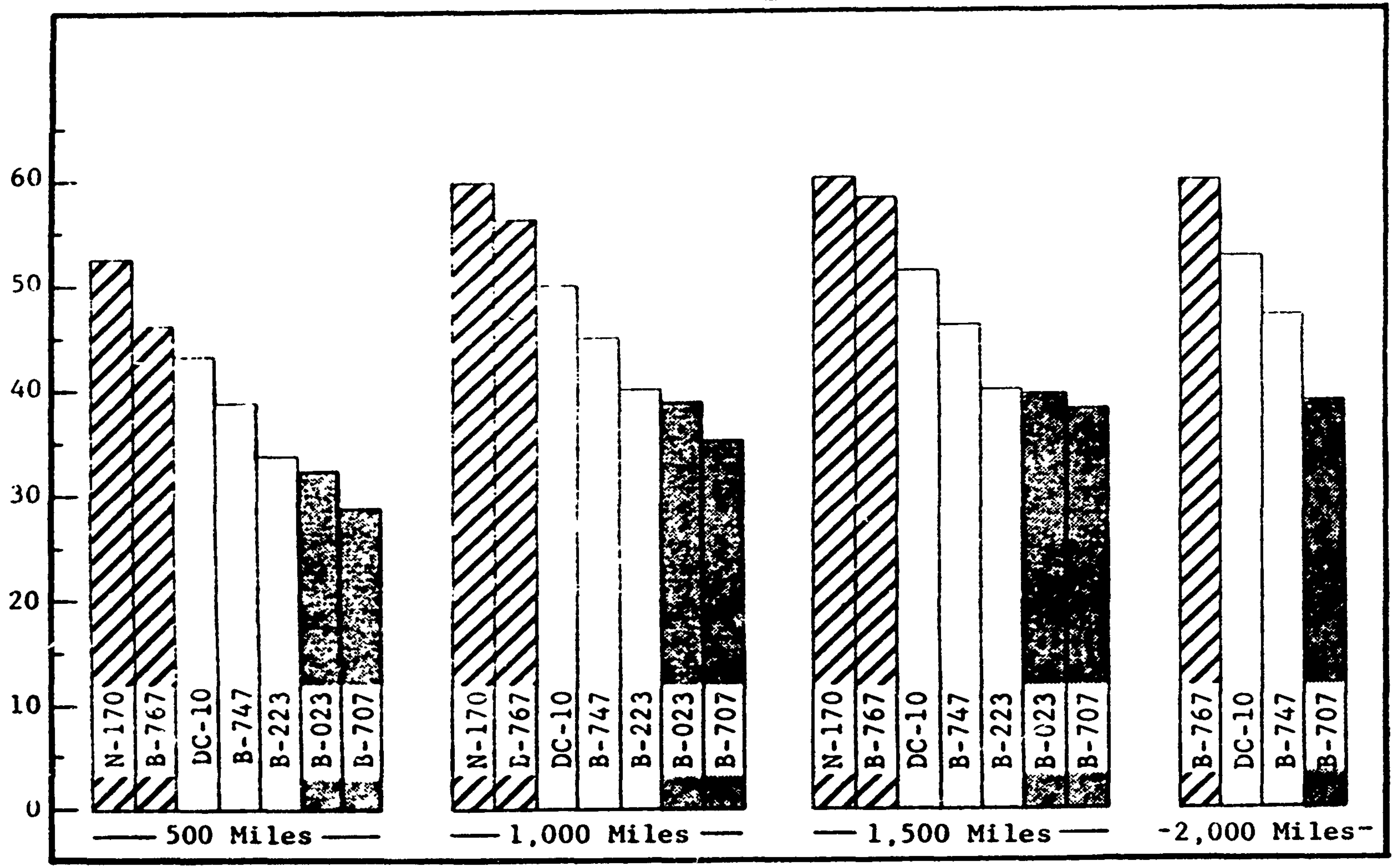


FIGURE 14

AIRCRAFT FUEL EFFICIENCY

A.S.M. PER GALLON



SPEECH BY DR HERBERT R LANDER JR

TECHNICAL AREA MANAGER, AERO PROPULSION LABORATORY

TO INDUSTRY - MILITARY ENERGY SYMPOSIUM

SAN ANTONIO, TEXAS

23 OCTOBER 1980

"USAF AVIATION FUEL TECHNOLOGY PROGRAMS"

I'd like to thank you for giving me the opportunity to review our jet fuel efforts. What I'd like to discuss today is our overall aviation turbine fuel technology program which is the title we use to describe research and development efforts to improve the availability of aviation fuel for the foreseeable future. Primarily I'd like to review an important technology which is a spinoff of this overall program. In our business we don't look at R&D as a means to itself. We look at R&D as a means to an end, and since we have total responsibility for Department of Defense aviation fuel, we'd like to think that the R&D we do leads to meaningful goals. Yesterday Jim McCoy discussed our R&D efforts in missile fuel development and that's an example of an area that we are proud of and something that impacted our cruise missile effort which is an important aspect of our strategic arsenal.

The areas I hope to touch upon today are outlined in this chart (vugraph 1). By the way if I don't follow these charts too well they will be described in the proceedings. I will attempt to stay away from details since time is limited, but I'd like to leave with you a feeling for our program and particularly the shale oil jet fuel initiative.

The next chart (vugraph 2) describes the general objective of our program which is to look at future fuels, where they might come from and try to get a better feel for what kind of characteristics they might have--realistic characteristics, not something that is only useful in filling textbooks, i.e. the effect of burning 95% aromatics in gas turbine engines. We try to get a feel for what is out there, keeping in mind that aviation turbine fuels are

critical materials. They have certain characteristics I'd like to feel are in the fuels in the aircraft that I fly in. If somebody else wants to use "junk" fuel they can but I certainly feel that certain characteristics are necessary to assure reliable performance. Some of the things Kurt Strauss mentioned concerning tradeoffs are exactly what we are considering in trying to get a feel for what are the options between the processing costs involved to produce jet fuel from all potential sources versus the costs of operating our equipment.

The next chart (vugraph 3) reviews the situation in this country with regard to future sources of fuel. If we are going to become domestically independent we're talking about this country. We're not talking about the Canadian tar sands. We're not talking about the Mexican oil; we're talking about what is indigenous to this country. Like any good government organization we went through a study phase where we looked at what was available, came to a conclusion and have embarked on pursuing that end. I think that some of the things we've done in the last seven years have been instrumental in what is slowly happening within this country, which is a realization that we're going to have to look at alternative sources. I don't want to go into any detail on this chart, it has been discussed by Kurt Strauss and probably discussed earlier in the symposium. One of the key factors early on was the fact that there is shale oil available in this country, a relatively unknown resource until several years ago. One of the primary reasons is that few people live there and consequently have little influence on the political scene in Washington because of a lack of a large number of representatives. So for this reason and others there's not a clamour within the US Congress to push off on shale oil development. I think within the last year or so its become evident that Western Oil shale is a tremendous resource which, along with coal and other fossil fuel sources, should be developed and together will begin to impact our dependence on foreign oil.

The next figure (vugraph 4) puts into perspective how the USA shapes up with the rest of the world. These resource estimates are subject to some assumptions; I will not go into all those details but simply present the numbers as rough estimates of what might be potentially available. Certainly,

our domestic petroleum reserves are small compared to the rest of the world; we'll probably have future discoveries which will hopefully increase these numbers, I certainly hope so. If we convert coal into liquid fuels the USA would have something bordering on nearly a trillion barrels in place. With tar sands we aren't as blessed as the Canadians; also our domestic tar sand deposits require different recovery techniques. The sixteen billion barrels are not probably all that attractive although R&D is proceeding on eventually recovering tar sand oil. Oil shale, and this is primarily the western oil shale, is on the verge of being commercialized once again. As you gathered from the announcement by Union Oil, on Tuesday, and also others in the coming year, there will be commercial development. Initially this will occur on private land. Eventually there will also be production on federal leases. This resource is enormous, in fact it's the largest hydrocarbon resource ever discovered by man and is relatively unknown outside of the territory where it is located. It also makes a good feedstock for middle distillate fuels. So in looking at our country from an energy standpoint, certainly coal and shale oil evolve as the main drivers in our search for improving our transportation fuels availability dilemma.

The next chart (vugraph 5) gets into the USAF program on evaluating how we could use fuels from these various sources and how we might be able to adapt to changing specifications, if necessary. Now, you'll have to pardon this chart; it was prepared five years ago when we expected to have national policy and expected to have significant input from both the DOD and DOE; we found out that it was like yelling into a well - all we heard was our echo. As a part of DOD we have worked closely with the other services. One of our primary cohorts in alternative fuels is the US Navy, and Mr Nowack will discuss their efforts later in this session. We've also worked closely with NASA, and I think we've had some impact on the direction which the current legislation has gone with regard to how synthetic fuels might be developed in this country. The USAF has placed itself in the position of being a potential customer for "synthetic" fuels. The USAF Turbine Fuel Technology Program is difficult to describe in words so we've put together what we refer to as the "Ferris Wheel" chart which describes the many facets of our effort which will enable us to

perform tradeoffs so that we will not "over specify" our fuels, but yet will impact both our current systems, where possible, and also influence future designs to be less fuel sensitive. We're concerned about processing costs, and will try to balance these versus their effect on fuel systems. Our primary concern as the Aero Propulsion Laboratory, since we have responsibility for developing gas turbine engines, is the combustion system. This is considered to be the most critical aspect of an aircraft. Certainly, the harshest environment is the temperatures in the "hot section" of the engine which includes both the combustor and turbine components. We have considerable effort in this area which I'll discuss a little later on. Other concerns are the overall fuel system, compatibility, the airframe and fuel handling. We don't want to have fuels that are difficult to handle or present us with some special environmental problems.

The next chart (vugraph 6) looks at the critical properties and the parts of the system where they apply. I don't want to discuss all of these characteristics. Some of these properties are interdependent in any given fuel. They cannot be carried independently. They are also a function of feed source and whatever process is used. We've grown used to fuels that are primarily distilled petroleum products and our systems are designed and constructed to use these fuels. Certainly, the most critical property we feel, looking at the overall system, is thermal stability. Being able to have a fuel which is not going to give us the problems either in storage or is not going to form deleterious gums or other particulates as we get to our engines is certainly one of the key concerns that had to be answered in a refined synthetic fuel.

In the overall program, the USAF will obtain as much flexibility as possible in our specifications in the future. We have looked at the various candidate fuels that might be produced. We have become interested in shale oil because it is similar to petroleum and has potential for affecting our availability problems which will become acute during this decade. The processing of shale oil has been investigated from the viewpoint of understanding whether shale oil was a good source of aviation fuel; in other words, were the yields and economics agreeable. Certainly we didn't want to pursue this source if the processing required more energy than was produced. If this had been the case perhaps shale oil would then make a better boiler fuel or diesel fuel or other product. This study was necessary in spite of the fact that we are in the Department of

Defense and have national security as our main concern; economics is also important. Every year we have a fuel bill of several billions of dollars; our projected bill for 1980 is nearly $4 billion. Certainly, the big spinoff of this effort would be its impact on the commercial aviation where economics are nearly as important as availability. Our effort basically involves looking at the various components of the system. Initially we have developed data on the effects of varying fuel properties on components in these systems and then proceeded into efforts to develop designs for overcoming fuel related problems. About two years ago, the USAF decided that domestic shale oil could drastically affect the jet fuel supply situation in the very near future. The USAF had studied shale oil derived fuel and felt that we could be the market for this particular "synthetic" fuel. This might be important in getting the development off the ground. Also in the back of our mind is the fact that we have many western bases that could use the fuel without inflicting large transportation or distribution costs. The USAF R&D community is currently working closely with the logistic side of the Air Force in an attempt to transition this technology into an operational mode. Colonel Charlie Moore, who will follow me in this session, will discuss that particular aspect. The basic general program has become a very specific aspect, namely, the impact of shale oil fuel on operational situations.

The next chart (vugraph 7) is a simplification of our overall schedule and outlines the shale oil acceptance program aspect of the effort. We will investigate full scale components with tests on the main burner and turbines. Next year we will look at the auxiliary power units and then at the fuel systems to determine what effect there is in using a shale oil derived fuel. Realize that we're talking about a near-term situation and we're going to meet our current specifications. We want to assure ourselves that these specifications are sufficient for a shale oil derived product. We will then progress into full-scale engines; these will be durability type tests and accelerated mission tests where we can, in 350 hours, reproduce what actually might occur in approximately 1000 hours of actual operation. We would then have a safe-to-fly test and, at this point, we would be in a position to look at the fuel operationally. Like I mentioned, Colonel Moore will discuss the operational aspects of the Air Force's program.

The next chart (vugraph 8) outlines some of the areas which the USAF is investigating under the title of "Fuel Characterization Testing." With shale oil derived JP-4, the fuel is characterized as being similar chemically to petroleum derived product.

Of primary concern was the suitability of shale oil as an economic source of jet fuel. The next chart (vugraph 9) outlines the main factors of the USAF research into shale oil upgrading and refining.

We weren't all sure about the quality of the fuel we would get on a continuous basis. We want to get a better feel for that. We wanted to take a look at both current refining technology which would be used in the early stages of synthetic fuel development and also that beyond the state-of-art which might give us a different quality of fuel later on near the turn of the century. We also want to take a look at some of the different crudes that were available to determine whether they required different processes for upgrading. We wanted to generate some fuel samples we could evaluate on smaller scale rigs. Therefore we went into programs that were stimulated from the highest levels of our organization, the Chief of Staff and the Secretary of the Air Force level.

The next chart (vugraph 10) outlines four phases of our programs looking into the shale oil refining technology. The first phase was a computer study of the refining techniques. The second phase was a bench scale evaluation of the techniques. The goal was to determine what kind of yields we were getting and how the processing economics were affected. The third phase was a pilot plant demonstration, running it for a number of months to get important information on catalyst deactivation which would certainly influence the overall economics of the operation. The fourth stage modifies the computer simulation to include the test data generated. And from our point of view we will learn something about the economics and something about the quality of the fuels. Also, as a result of these efforts, information will be generated whereby the refiner might obtain information needed to modify existing refineries or build grass root refineries for converting shale oil.

The next chart (vugraph 11) is not all that complicated but time prohibits me from discussing the various technologies that are being investigated by the

contractors. We have three research contracts with Sun Oil Co., Ashland Petroleum and UOP Process Divisions. The programs take a look at different methods for upgrading, nitrogen removal and hydrogen enhancement which are necessary for shale oil derived materials. Also, the boiling curve must be redistributed if we are going to produce middle distillates. For JP-4 production we have to produce light ends for the required altitude relight situations and some of the heavy ends must be pyrolyzed to get around any possible freezing point problems. In approximately one month in Cincinnati, Ohio, we'll have an in-depth technical review of these three programs discussing the various techniques being used and the economics involved.

The next chart (vugraph 12) outlines the economics for the three programs and also the potential yields if you want to produce large quantities of JP-4 jet fuel. We found that,indeed, shale oil is a good source of aviation turbine fuel or, for that matter, any other middle distillate material. The yields could be at least 50% if you really want to recycle and hydrocrack to extinction you could come up with yields of approximately 90%. For JP-8 and JP-5 the yields, perhaps, are less than for JP-4 but shale oil is still a good source of these fuels. An indepth analysis of the economics turns out to be attractive based on each of the processes. The biggest unknown here is the cost of a barrel of shale oil crude, and that varies depending on who you talk to, what recovery technique they are going to use, and how much the resource has cost them.

The next chart (vugraph 13) addresses the testing carried out on the fuels that we are considering and particularly the shale oil fuel. This is an ongoing program looking at the main burner and turbine components of a full scale engine. We get a feel for the durability and the performance in the combustor and also the effect on the turbine. We have incorporated shale oil jet fuel into this effort. The shale oil JP-4 meets our specifications. We have two efforts, one with the General Electric Company and one with Pratt & Whitney looking at five different combustor types from five different operational engines. The types of testing are combustor and turbine component rig tests and there will be some selected fuel engine tests. The results of looking at

the shale oil fuel have been completed and we see really no difference between using the shale oil derived JP-4 as compared to petroleum derived JP-4. We'd be surprised if we did. There was some concern there may be some trace materials that might be carried over, but the upgrading of shale oil to remove nitrogen is a harsh treatment and using the state-of-the-art hydrogenation techniques produces a "reagent grade" material.

The next chart (vugraph 14) gives the current status of our program. We're conducting tests in the shale oil evaluation program to enable us to determine whether shale oil derived fuels are compatible with conventional aircraft and again I want to stress these are fuels that are refined to meet our current specification. The Defense Fuel Supply Center (DFSC) has initiated a refining program which will produce up to 20,000 barrels of shale oil derived JP-4 which will be used in the next stage of our program which is the durability test on engines. The DOD,as part of a joint effort with the Department of Energy,will help to implement the provisions of the Security Act of 1980 which will lay out incentives like guaranteed markets, loan guarantees, front-end money, etc. The Air Force eventually could be required to use not only shale oil derived fuel but perhaps even fuel that is produced from feedstock such as coal liquids. We do have interest in the potential of coal liquids as a refinery feedstock. We feel that this is probably downstream a little bit further but certainly we want to be prepared when this occurs.

In the summary of our program (vugraph 15) we feel that synthetic fuels are going to certainly play a key role in the fuel availability situation with regard to the Air Force in the future. Shale oil is the most viable alternative to petroleum from its nearness to commercialization and also its chemical resemblance to petroleum. Fuel specifications must be flexible. We must be able to adapt to whatever sources are eventually included and, in the long term, our specifications will be flexible. The Air Force is planning to use shale oil derived JP-4 as early as 1983 and we hope to be in the position to embark on this program. Colonel Moore will discuss this later this morning. We have laid out a program which looks at the research and development and also what is necessary as far as moving from an R&D situation into an operational situation.

We believe our programs are well laid out. We have involved everybody from the R&D community, the logistics side and those who build, use and fly aircraft. The initial meeting on our operational validation program was held in the Pentagon in January 1980. And that pretty well covers what I wanted to discuss this morning. Thank You.

VUGRAPH 1

OUTLINE

- OBJECTIVE
- BACKGROUND
- AIR FORCE PROGRAM
- DOD DIRECTIVE
- AIR FORCE INITIATIVE

VUGRAPH 2

OBJECTIVE:

EVALUATE THE POTENTIAL CHARACTERISTICS OF FUTURE JET AIRCRAFT FUELS, DETERMINE EFFECTS ON ENGINE COMPONENTS & EVOLVE COMPONENT TECHNOLOGY IF NEEDED.

APPROACH:

- IDENTIFY DEGREE TO WHICH FUEL SPECIFICATIONS MAY BE RELAXED.
- DETERMINE EFFECTS OF RELAXING FUEL SPECIFICATIONS ON DESIGN OF:
  - COMBUSTORS
  - TURBINES
  - FUEL TANKS
  - FUEL SYSTEMS
  - MATERIALS
- PERFORM ENGINE DEMONSTRATION TESTS WITH CANDIDATE ALTERNATE FUELS.

VUGRAPH 3

DOMESTIC SOURCES OF HYDROCARBONS

- CONVENTIONAL PETROLEUM - INADEQUATE
- HEAVY OIL - WILL AUGMENT SUPPLY (NEAR TERM)
- TAR SANDS - MINOR CONTRIBUTION
    - RESOURCE SMALL
    - OWNERSHIP QUESTIONABLE
- COAL - FUEL FOR STATIONARY POWER, GASOLINE
    - LARGE RESOURCE
    - POSSIBLE BLENDING COMPONENT TO EXTEND TURBINE FUEL SUPPLY
- SHALE OIL - IDEAL FOR TRANSPORTATION FUELS
    - LARGE RESOURCE
    - RESEMBLES PETROLEUM
    - NEAR COMMERCIALIZATION

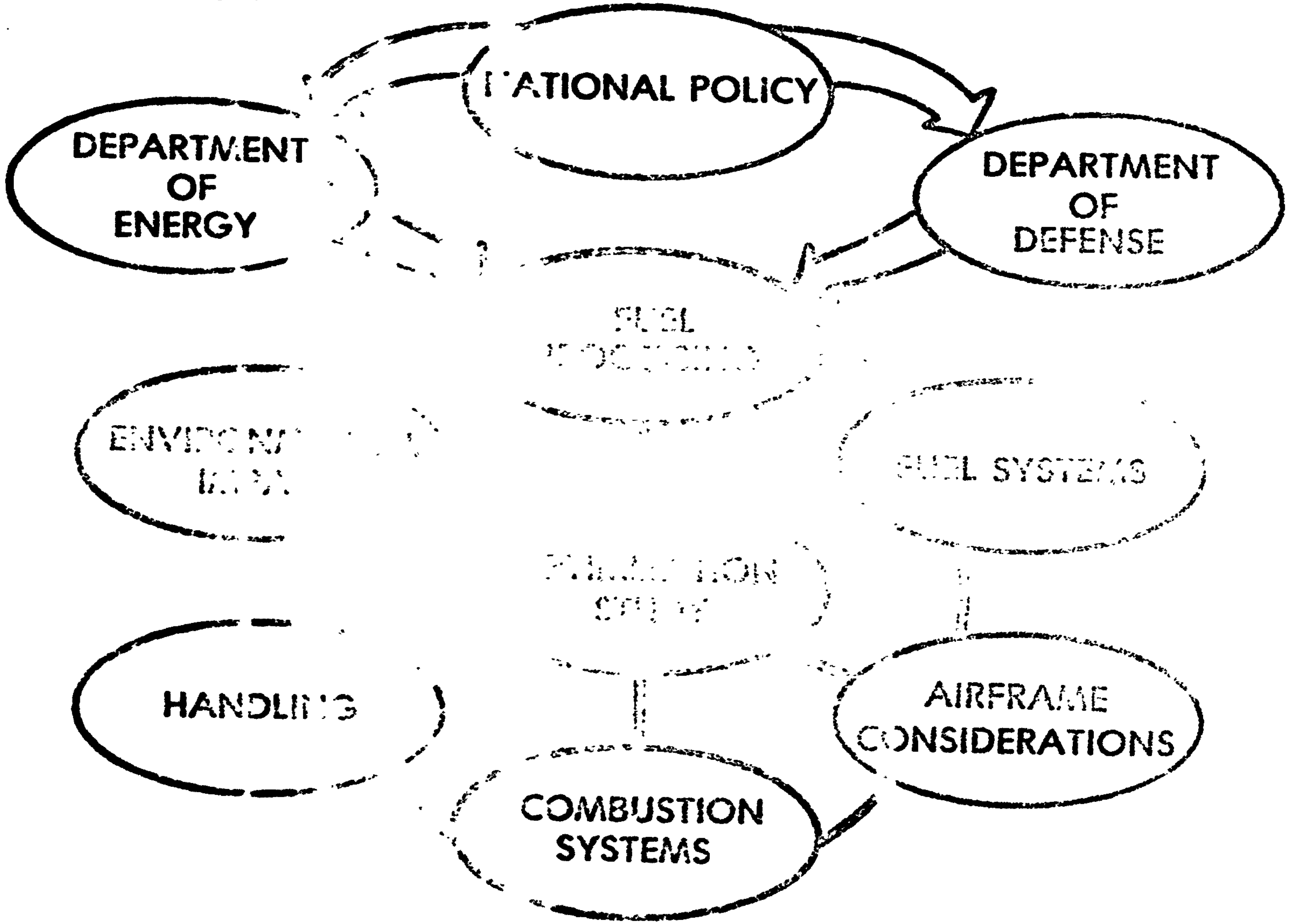
VUGRAPH 4

SUMMARY OF WORLD RECOVERABLE FOSSIL FUELS
(BILLIONS OF BARRELS)

	WORLD	USA
OIL	716	35
COAL	2,600	800
TAR SANDS	956	16
OIL SHALE	1,463	1,063
TOTAL	5,735	1,914

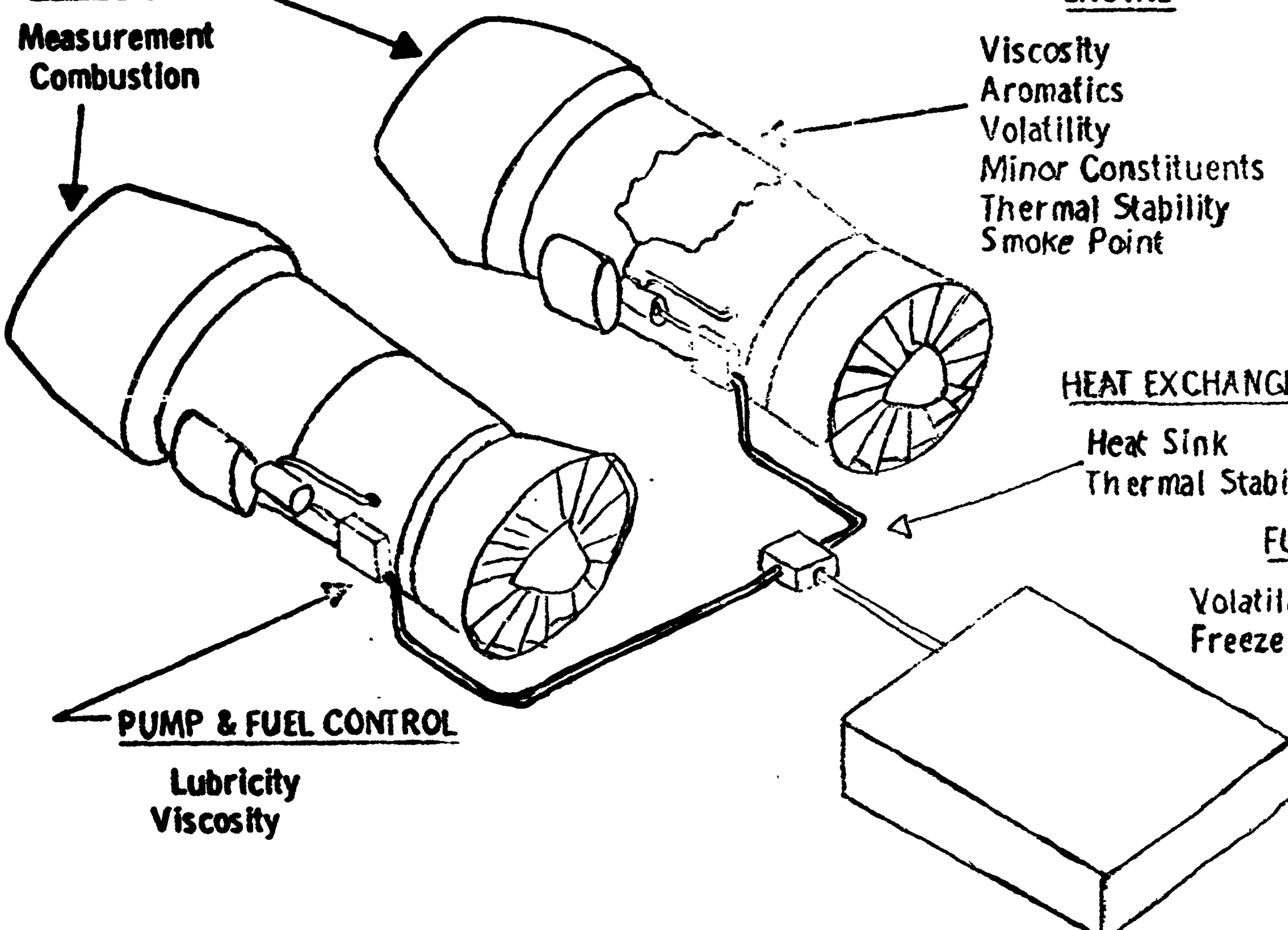
VUGRAPH 5

USAF AVIATION TURBINE FUEL TECHNOLOGY PROGRAM



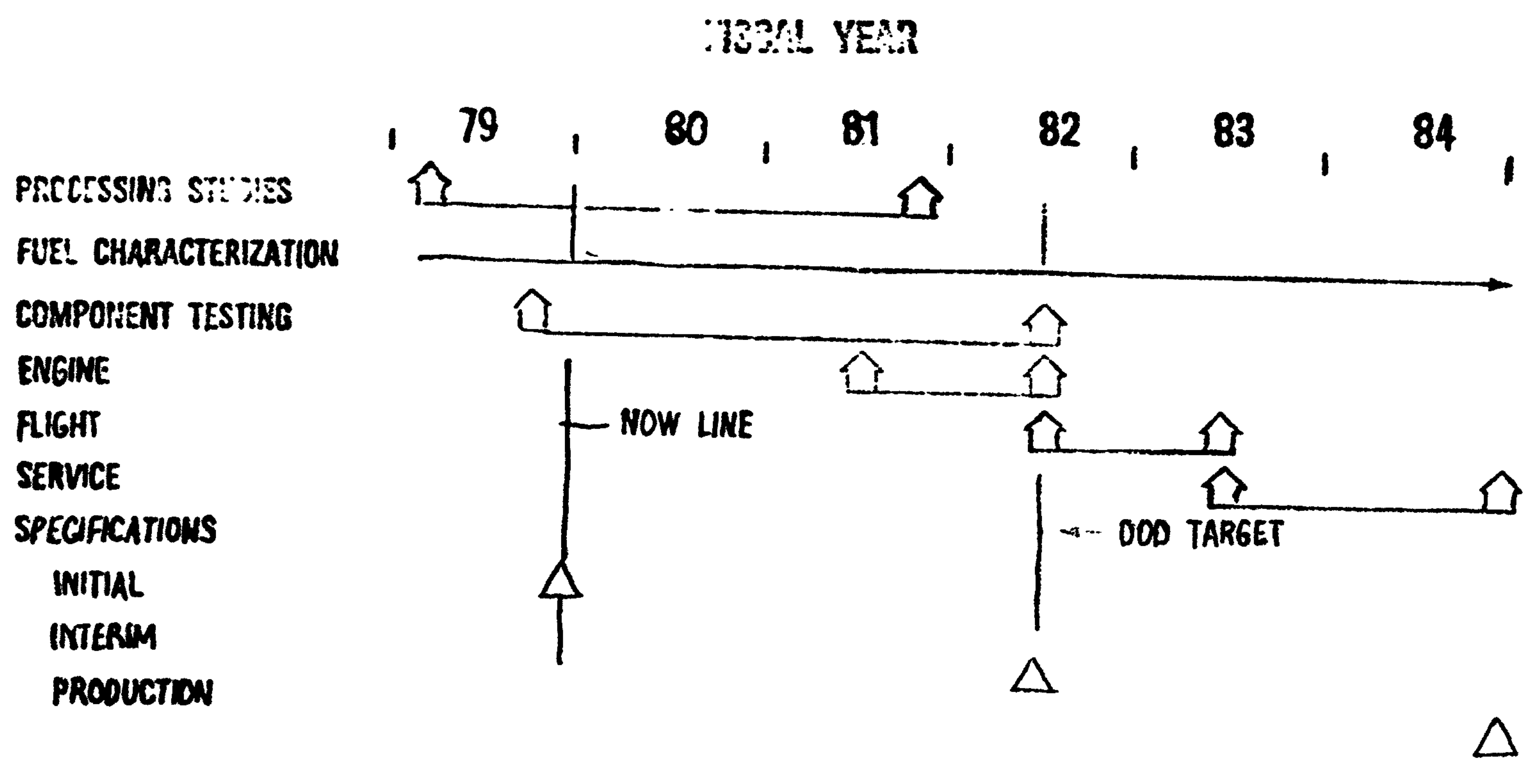
VUGRAPH 6

ENGINE - FUEL INTERFACE



VUGRAPH 7

AIR FORCE SHALE OIL ACCEPTANCE PROGRAM



VUGRAPH 8

FUEL CHARACTERIZATION TESTING

- CHEMICAL ANALYSIS
- MATERIAL COMPATIBILITY
- TOXICITY
- FUEL HANDLING

VUGRAPH 9

JET FUEL FROM SHALE OIL

- ESTABLISH ECONOMICS AND YIELDS FOR VARIABLE QUALITY JET FUEL
- CURRENT AND NEAR-TERM REFINERY TECHNOLOGY
- ABOVE GROUND AND IN-SITU CRUDES
- FUEL SAMPLING

VUGRAPH 10

JET FUEL FROM SHALE OIL

- CONTRACTORS
  - ASHLAND PETROLEUM
  - SUNTECH (SUN OIL)
  - UOP PROCESS DIVISION

- PROGRAM PHASES

  PHASE I: PRELIMINARY PROCESS ANALYSIS
  PHASE II: BENCH-SCALE TESTS
  PHASE III: PILOT PLANT TESTS
  PHASE IV: OVERALL ECONOMIC EVALUATION

VUGRAPH 11

SHALE OIL PROCESSING STUDIES

	ASHLAND	SUNTECH	UOP
NITROGEN REMOVAL	FLUID CATALYTIC CRACKING AND LIQUID EXTRACTION	HYDROGEN CHLORIDE TREATMENT	MODIFIED RECYCLE
HYDROGEN ENHANCEMENT	REDISTRIBUTE BY FCC - HYDROTREAT	HYDROCRACKING HYDROTREAT	MODIFIED RECYCLE HYDROCRACKING HYDROTREAT
BOILING RANGE CONVERSION	FLUID CATALYTIC CRACKING	HYDROCRACKING	MODIFIED RECYCLE HYDROCRACKING
ADVANTAGES	REDUCED H_2 CONSUMPTION HIGH JET FUEL YIELDS	REDUCED H_2 CONSUMPTION HIGH JET FUEL YIELDS	LOW RISK HIGH JET FUEL YIELDS

VUGRAPH 12

JP-4 YIELD AND COST DATA

PROCESS/ PRODUCTS	LIQUID YIELD * (%)	JP-4 YIELD * (%)	PRODUCT COST ** (¢/GAL)
ASHLAND			
JP-4/DF-2/GASOLINE	86.8	47.2	81
SUNTECH			
ALTERNATE I	94.1	94.1	84
ALTERNATE II	86.8	86.8	92
UOP INC			
MAX JP-4	95.4	95.4	83
JP-4/DF-2	95.8	75.0	81
JP-4/DFM	95.3	67.1	81

* BASED ON VOLUME % OF FEED

** SHALE OIL CRUDE COST, ESTIMATED $25 / BARREL

VUGRAPH 13

USAF FUEL COMBUSTOR/TURBINE EFFECTS

OBJECTIVE:

- QUANTIFY THE EFFECTS OF FUEL PROPERTY VARIATIONS ON:
  - (1) COMBUSTOR PERFORMANCE/DURABILITY
  - (2) TURBINE PERFORMANCE/DURABILITY
  - (3) ENGINE TRANSIENT OPERATION
- EVALUATE THE SYSTEM EFFECTS OF OIL SHALE DERIVED JP-4

APPROACH:

- SYSTEMS TO BE EVALUATED:
  - (1) GE - J79, J85, TF39
  - (2) P&W - J57, F100
- TYPES OF TESTING:
  - (1) COMBUSTOR AND TURBINE COMPONENT RIG TESTS
  - (2) SELECTED FUEL ENGINE TESTS

VUGRAPH 14

CURRENT STATUS

USAF SHALE OIL ACCEPTANCE PROGRAM

- US AF IS CONDUCTING A TEST AND EVALUATION PROGRAM TO ASSURE COMPATIBILITY OF SHALE FUEL WITH AIRCRAFT SYSTEMS.
- DFSC HAS INITIATED A REFINING PROGRAM TO PRODUCE SHALE DERIVED TEST FUELS IN 1981.
- DOD, INCLUDING USAF, ARE PARTICIPATING WITH DOE TO IMPLEMENT THE PROVISIONS OF THE ENERGY SECURITY ACT OF 1980.
- USAF WILL BE REQUIRED TO USE SHALE AND COAL DERIVED FUEL IF PRODUCED UNDER DPA AMENDMENT.

VUGRAPH 15

SUMMARY

- USAF JET FUEL AVAILABILITY DEPENDENT ON SYNTHETIC FUELS
- SHALE MOST VIABLE DOMESTIC ALTERNATIVE SOURCE
- FUTURE SPECIFICATIONS MUST BE FLEXIBLE SO AS TO INCLUDE SYNTHETIC FUELS
- USAF PLANNING TO USE SHALE DERIVED TURBINE FUEL IN 1983
- R&D AND VALIDATION PROGRAM REQUIRED TO ASSURE SMOOTH TRANSITION TO SHALE DERIVED FUEL

NAVY MOBILITY FUELS RDT&E PROGRAM

NAVAL AIR PROPULSION CENTER
TRENTON, NEW JERSEY
C. J. NOWACK, PROGRAM MANAGER

(1)*

NAVY MOBILITY FUELS RDT&E PROGRAM

The Naval Air Propulsion Strategy points out the need for fuels with a wider permissible range of characteristics and a requirement for the development of the tools and methodology for testing the impact of these changes on aircraft hardware performance. The Navy's Mobility Fuel RDT&E program (1) is designed to identify those problems associated with aircraft fuel property and chemical compositional changes and to provide guidelines for the development of advanced hardware to use fuels that do not conform to the current fuel specification. Therefore, the thrust of this work will enable maximum flexibility in the use of hydrocarbon fuels, so that availability will be enhanced without unacceptable restraints. The technology developed in this program can be applied to synthetic fuels derived from oil shale, and it is also anticipated that such technology will be applied to the solution of service problems due to unpredictable deleterious reactions at the fuel wetted surfaces.

The technology developed in this program will be applied to solving both current and future fuel availability problems.

Problem Statement (2)

1. Naval operations overseas are largely dependent upon foreign sources for aviation fuel supplies. In the event that petroleum crude supply to these overseas refineries is disrupted, the supply of Navy JP-5 would suffer a shortfall, and thus reduce the Navy's air combat readiness. In such situations the Navy may be forced to use alternate fuels, for example, non-aviation kerosenes which have similar distillation characteristics to JP-5. In emergency situations the Navy must be flexible and learn to use for short periods available fuels that do not conform totally to the current specification for JP-5. To develop fuel flexibility capabilities requires extensive aircraft component hardware and engine testing to identify the impact of using non-aviation fuels on the performance and durability of existing aircraft.

2. The Navy is currently experiencing local shortages of JP-5. Shortages are occurring because some of the smaller refineries that supply the Navy with JP-5 lack the hydrotreating equipment required to produce a fuel with an acceptable level of aromatics. The Naval Air Propulsion Center (NAPC) has the technical responsibility to make decisions on acceptance or rejection of these off-specification fuels. Presently there is little quantitative evidence to support the waiver of an off-specification fuel, since there exists insufficient data on the durability of Navy combustors using a higher than the acceptable aromatic limit JP-5 fuel. To obtain the necessary durability information requires an extensive aircraft engine system test program to document the effects of such fuels on Navy combustion systems.

3. Changes are occurring in the petroleum refinery industry which are affecting the properties and composition of JP-5 to the extent that the Navy is experiencing aircraft service problems. The two main problems are pump and fuel control failure due to low lubricity fuels, and elastomeric deterioration from fuel instability. Low lubricity and instability are not covered by the specification and are the result of the severe hydroprocessing currently used in the production of JP-5 from lower quality, high sulfur crudes. It is the opinion of many

*Numbers in parenthesis refer to viewgraphs.

technical experts that the high severity hydrotreatment is removing natural lubricants from the fuel that provide lubricity for pumps and fuel controls, as well as natural oxidation inhibition that provides stability. To cope with these service problems, additives are used to restore fuel lubricity and stability, however the use of additives is nothing more than putting a bandage on the problem. This is not the preferred solution. The use of an additive may eliminate some existing problem, but they generally cause problems to the fuel handling equipment because of their surface activity. Therefore, the Navy would prefer to correct fuel related hardware problems by modifying the aircraft components to be more tolerable and compatible with low lubricity and unstable fuels. To initiate such development programs requires first the construction of laboratory tools to measure and verify the impact of low lubricity and unstable fuels on equipment design and performance.

4. The worldwide petroleum resources are depleting and shortages of fossil fuels are imminent. Since the Navy's current and future aircraft propulsion systems are completely dependent upon hydrocarbon fuels, availability problems will no doubt occur before the turn of the century. With this thought in mind the Navy has been continually conducting programs to qualify alternate sources of fuels, such as coal and oil shale. Recently the Navy has investigated the suitability of an oil shale derived JP-5 for use in Navy aircraft components and engines. Such studies are laying a technology base for qualifying future quantities of oil shale JP-5 which will be available in the post 1985 time frame.

The overall goal of the Navy's Mobility Fuel RDT&E Program is to address fuel availability problems with an aggressive thrust. The developed technology will enable the Navy to procure the needed fuel and operate with hydrocarbon fuels of the future in an era of rapidly changing crude sources and technology, while at the same time eliminating or minimizing supply and operational problems and maintaining mission capability. Therefore, the objective (3) of this program is to develop the capability to operate on a wider variety of fuels by determining the impacts of changes in fuel properties and chemical composition on aircraft propulsion and auxiliary systems. This capability will provide predictability as to the acceptability of new fuels and will allow determinations of necessary hardware changes to accommodate new fuels. This can be stated another way, the work conducted in this program will identify technical areas that can be improved upon to make Navy engines more fuel tolerant, therefore being more fuel flexible.

The approach to this program is schematically outlined in a program plan format (4). This plan can be effectively applied to the study of new fuels derived from petroleum and syntheitc crudes. The extent to which the plan is applied, especially in the hardware component phase will depend upon the degree to which the new fuel deviates from the current specification. The flexibility of the plan also permits its utilization in studying current specification JP-5 fuels that cause serivce problems due to unexplained variations in the chemical composition that are not detected by the routine laboratory specification tests. In conducting a thorough study the Navy firmly believes that an essential part of the program is to maintain a constant surveillance of the changes occurring in the petroleum refinery industry. Keeping a finger on the pulse of refinery production trends (5) guides the direction of the overall program by identifying those fuel properties that are currently affecting availability. For example, two properties aromatics and freeze point were identified as being restrictive and relaxation of these limits would increase the yield of JP-5. From this information the Navy is currently evaluating the impact of higher aromatic and

freezing point fuels on the performance and mission capability of Navy aircraft. The study of production trends is not limited to availability. There are changes occurring in the refinery industry such as reduction in crude quality and the introduction of new processes to handle these crudes. These studies are important since they attempt to identify those refinery variables which are affecting JP-5 composition in such a way that the Navy is experiencing service problems with specification fuels. Exxon Research and Engineering Company has just completed an 18 month study for the Navy (No. N00140-78-C-1491) identifying potential fuel problems that could be caused by the evolution of petroleum refinery technology.

The Navy is quite active in developing in-house capabilities for studying the fundamentals of fuel chemistry (6). These investigations emphasize the chemical aspects of fuel development by characterizing the hydrocarbon/non-hydrocarbon types that affect fuel properties. This work is being conducted by the Naval Research Laboratory (NRL) and addresses the interrelationships between fuel chemistry and observable properties of new fuels that have relaxed properties relative to the current JP-5 specification. It is anticipated these fundamental relationships will also be used to establish mechanisms of deleterious reactions at fuel/hardware interfaces resulting from changes in fuel composition due to the changes occurring in today's petroleum refinery industry. The fuel characterization studies are being conducted with current analytical methods as well as advanced techniques such as, high performance liquid chromatography, field ionization mass spectroscopy and nuclear magnetic resonance C_{13} spectroscopy. The work is also addressing the development of new test methods to characterize the properties of existing or new fuels that are not defined by existing test procedures.

NAPC fuel research laboratory has been continuously engaged in the development and improvement of research tools to be used for studying fuel behavior in a simulated environment (7). The objective of this work is to provide the Navy with the research capabilities to study new fuels and establish defined relationships between fuel properties and aircraft hardware, engine component and fuel handling equipment performance. Although this technology will permit the Navy to assess on a laboratory scale the impact of using new fuels with relaxed specifications it must be emphasized that the results of these studies do not imply immediate acceptance of the fuel for service use. The data obtained in the laboratory with bench scale equipment produces only indications and trends of fuel behavior in full scale engine equipment. The improvement in the reliability of such laboratory scale tool measurements can only be validated through correlations with the actual full scale equipment, which the laboratory tools only intend to simulate. For example, the laboratory test for lubricity is the Ball-on-Cylinder Machine (BOCM). Currently the BOCM has the sensitivity to differentiate between a low, moderate and a high lubricating jet fuel. This BOCM data are meaningless unless full scale pump and control durability tests are conducted and a relationship developed bewteen the full scale data and the BOCM results. The development of in-house capabilities, that is laboratory tools is an essential part of fuel development. Laboratory tools are necessary screening procedures for evaluating the acceptability of new fuels because such tests are rapid and do not require large quantities of costly experimental fuels. These tools will differentiate which fuels are marginal or totally unacceptable. Marginal fuels which show potential use for aircraft are then procured in larger quantities for further evaluation in full scale component and engine tests.

An essential part of the Navy Mobility Fuels Program is full scale hardware component and engine testing, which will be conducted both in-house and by contract (8). The purpose of these tests will be used to establish a quantitative relationship between

fuel property variables and aircraft hardware performance and durability limits. The tests will be conducted using experimental fuels having a range of critical properties that extend beyond the current required limits. The experimental fuels that will be used in these tests are off-specification fuels, relaxed specification fuels and synthetic fuels. The off-specification fuel will have an aromatic limit in the range of 25-30% and is representative of some of the fuels the Navy is currently rejecting because of unacceptable high aromatics. The relaxed specification fuel will have several properties outside the current limits, such as aromatics 25-35%, freezing point -45°F, and a distillation end point between 560-590°F. The Navy has just completed a study with synthetic JP-5 type fuel derived from oil shale. This fuel was part of the 100,000 barrel crude shale oil full scale refinery project that was conducted in the latter part of 1978. This fuel was run in a full scale combustor and engine, and preliminary data indicate the fuel gave equivalent performance to petroleum derived JP-5. Although the fuel did performance satisfactorily the laboratory uncovered some problems related to poor lubricity and storage stability in addition to some corrosive tendencies with copper. All three property deficiencies were corrected with additives. Also another added importance of any full scale component engine tests is to provide base line data to judge the validity of any new test methods or concepts being developed for the purpose of minimizing the need for full scale engine testing of new fuels.

In addition to the laboratory and full scale investigations just described the Navy has a parallel effort to study new improved fuel acceptance methods (9) to be used in qualifying new fuels. This project has been entitled, "The Development of Alternate Test Procedures (ATP) for Qualifying New Fuels". The project is a two phase study and the first phase will be completed early in 1981. The continuation of Phase II will be dependent upon the results of Phase I. Phase I provides for the study and recommendation of fuel test procedures that will quantitatively reflect the sensitivity of Navy aircraft engines to those changes in fuel properties. This phase also will provide for the study of jet fuel development trends to make judgements concerning those fuel properties and compositional differences that may exist in new fuels. The study of fuel trends is for the purpose of recommending referee fuel formulations to be used in Phase II for demonstrating the reliability of the ATP to predict fuel variable effects. The ATP is at the Phase I level under contract to Pratt and Whitney Aircraft and Southwest Research. The Navy felt it wise to have a multiple award on this effort for two reasons. First, the combined effort of the two contractors will study the fuel sensitivities of all Navy engines currently in inventory. This coverage is important since it has been the Navy's experience that engines behave differently to differences in fuel properties and composition, therefore, it is extremely important that each engine type be investigated. Second, each contractor had a different approach to the development of the ATP. Since this is a new concept being developed the Navy felt it judicious to investigate both approaches.

The Program just described is a four year effort (10) starting in 1980 and terminating in 1983.

NAVY MOBILITY FUELS RDT&E PROGRAM

PROBLEM STATEMENT

- NAVY OVERSEAS FUEL SUPPLY IS VULNERABLE
- LOCAL SHORTAGES OF JP-5 EXISTS
- CHANGES IN REFINERY VARIABLES ARE AFFECTING JP-5 PROPERTIES AND COMPOSITION
- PETROLEUM RESOURCES ARE DEPLETING

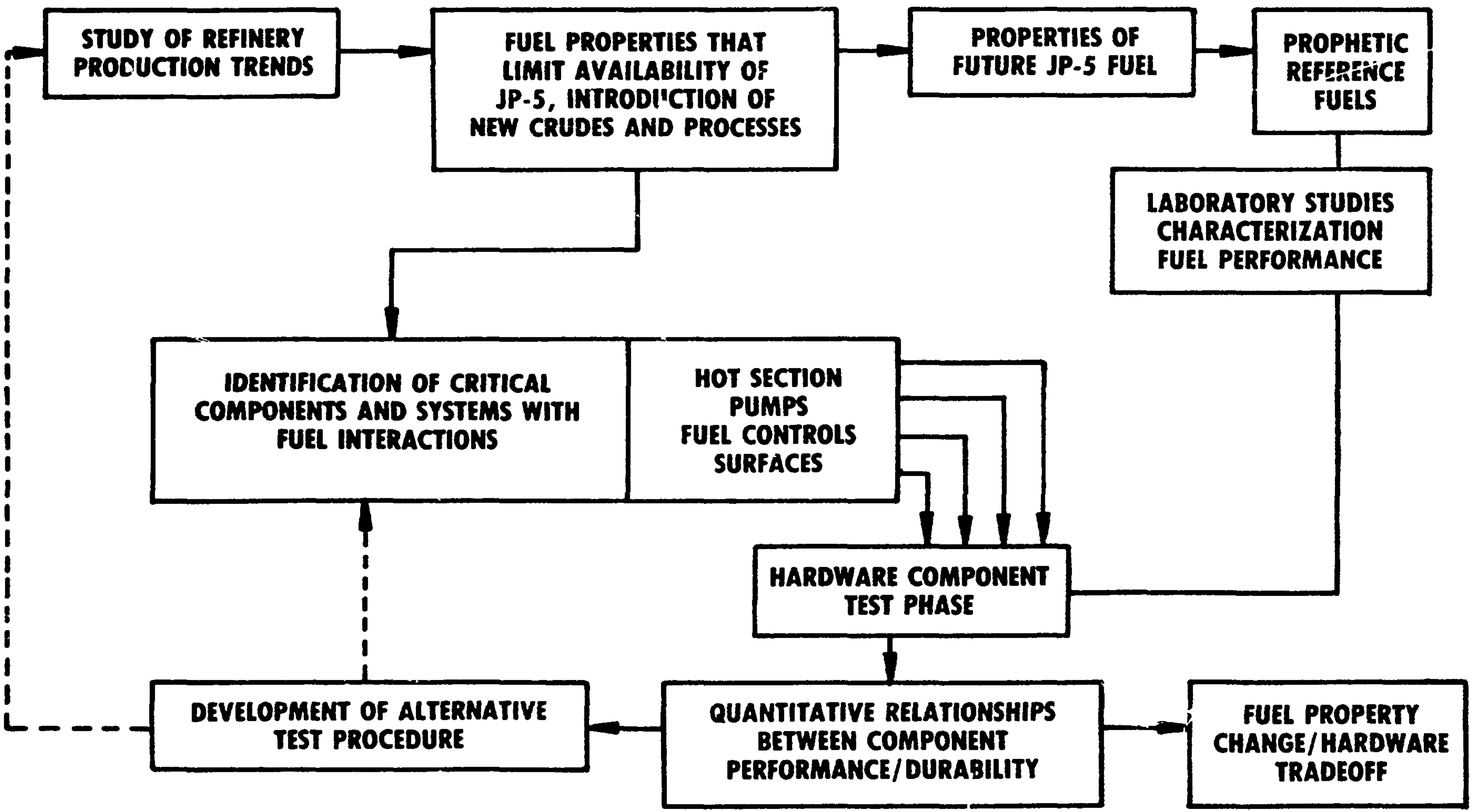
NAVY MOBILITY FUELS RDT&E PROGRAM

OBJECTIVE

- DEVELOP A CAPABILITY TO OPERATE ON A WIDER VARIETY OF FUELS WITHOUT SIGNIFICANTLY DEGRADING PERFORMANCE

NAVY MOBILITY FUELS RDT&E PROGRAM

PROGRAM PLAN



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NAVY MOBILITY FUELS RDT&E PROGRAM

REFINERY PRODUCTION TRENDS

- ESTABLISH FUEL CHARACTERISTICS THAT AFFECT AVAILABILITY; PROCURE FUELS FOR TEST PURPOSES
- IDENTIFY REFINING VARIABLES (CRUDE AND PROCESS CHANGES) THAT AFFECT JP-5 COMPOSITION (1)
- STUDY POTENTIAL FUEL PROBLEMS THAT ARE CAUSED BY REFINERY VARIABLES

(1) EXXON CONTRACT NO. N00140-78-C-1491

NAVY MOBILITY FUELS RDT&E PROGRAM

DEVELOP IN-HOUSE CAPABILITIES (NRL)

- TO CHEMICALLY CHARACTERIZE NEW FUELS AND ESTABLISH RELATIONSHIP BETWEEN FUEL CHEMISTRY AND PROPERTIES
  - PONA ANALYSIS BY HPLC, FIMS, NMR-C_{13}
  - DEVELOP NEW SPECIFICATION TESTS WHERE NEEDED
  - ESTABLISH MECHANISMS FOR STORAGE/THERMAL STABILITY

NAVY MOBILITY FUELS RDT&E PROGRAM

DEVELOP IN-HOUSE CAPABILITIES (NAPC)

- TO ESTABLISH RELATIONSHIP BETWEEN FUEL PROPERTIES AND PERFORMANCE
  - STORAGE/THERMAL STABILITY (ALSO CONTRACT)
  - LUBRICITY
  - COMBUSTION
  - COALESCENCE
  - COLD FLOW
  - MATERIAL COMPATIBILITY

NAVY MOBILITY FUELS RDT&E PROGRAM

AIRCRAFT COMPONENT/ENGINE TESTS (IN-HOUSE AND CONTRACT)

- TO ESTABLISH PERFORMANCE/DURABILITY LIMITS
  - OFF-SPECIFICATION JP-5
  - RELAXED SPECIFICATION FUEL
  - SYNTHETIC FUELS
  - VALIDATE NEW METHODS OF QUALIFYING NEW FUELS

NAVY MOBILITY FUELS RDT&E PROGRAM

DEVELOP IMPROVED FUEL ACCEPTANCE METHODS (1)

- TWO PHASE PROGRAM
  - PHASE I (10 MONTHS)
    - AIRFRAME/ENGINE ENGINEERING ANALYSIS
    - JP-5 SPECIFICATION FORECAST FOR 1990
    - FORMULATION FOR REFEREE FUEL
    - RECOMMEND ALTERNATE TEST PROCEDURE (ATP) TO QUALIFY NEW FUELS WITH A MINIMUM OF ENGINE TESTS
  - PHASE II (ABOUT 18 MONTHS)
    - DEMONSTRATE ATP

(1) CURRENTLY UNDER CONTRACT - PRATT & WHITNEY N00140-80-C-0269
- SOUTHWEST RESEARCH N00140-80-C2265

NAVY MOBILITY FUELS RDT&E PROGRAM

SCHEDULE

(1) REFINERY PRODUCTION TREND ANALYSIS

(2) IN-HOUSE LABORATORY STUDIES

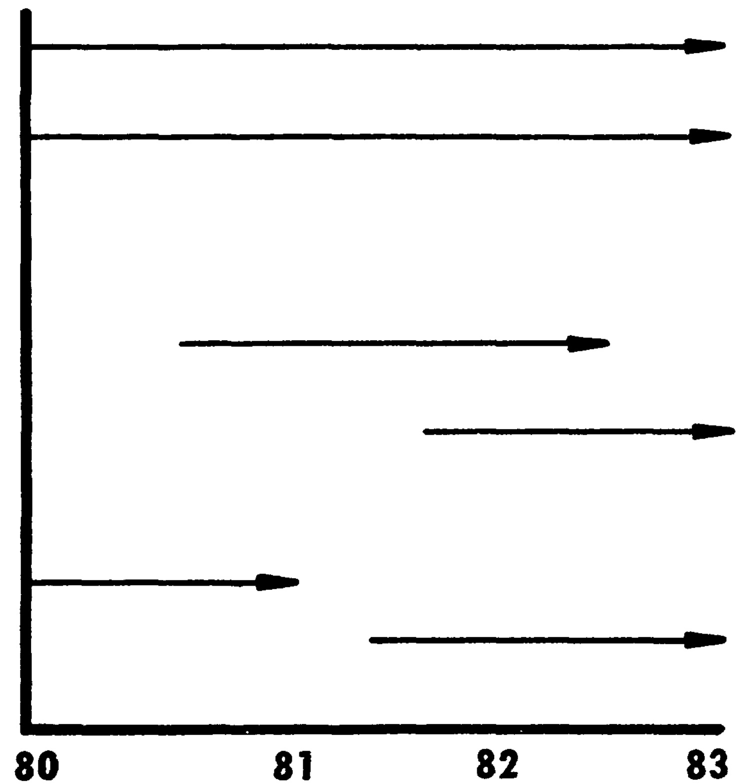
- LABORATORY FUEL PERFORMANCE STUDIES
- CHEMICAL CHARACTERIZATION

(3) ENGINE COMPONENT STUDIES

(4) FULL SCALE ENGINE

(5) ALTERNATE TEST PROCEDURE

- PHASE I
- PHASE II



USAF SHALE OIL VALIDATION PROGRAM

PRESENTED BY

COL CHARLIE B. MOORE
HQ USAF
ENERGY MANAGEMENT

PRESENTED TO THE
INDUSTRY-MILITARY ENERGY SYMPOSIUM
21-23 OCTOBER 1980
SAN ANTONIO, TEXAS

USAF SHALE OIL VALIDATION PROGRAM

VG-1

This Air Force requirement list shows you how requirements are distributed. You see the requirements on the East coast, inland and on the West coast, that is around here, up north where our Strategic Air Command is located and where we do a lot of our tactical flying. We have large demands inland and on the West coast, surrounding the shale oil deposits. We also have overseas demands as well.

VG-2

We have been in the business a long time. We are not newcomers to the business. This chart tries to show that. This has a non linear time scale which starts in 1915 when the Navy first took over Shale oil reserve out there in Colorado with the intention of utilizing that for sea systems. They have had a couple of programs, a 10,000 barrel program out of that reserve, 100,000 barrel program. We are now in the process of testing the fuels from those programs. We have flown a T-39 on this. There is no question that the stuff works in airplanes, it is just a question of whether the airplanes work very long on the stuff. We, and NASA, took a very early look into whether we wanted to be in the shale or in the coal business. In examining our requirements and the technology at that time, we decided that shale was the way we ought to be going. We and the Navy had been working together on these programs trying to get a Department of Defense activity moving. Unfortunately, the Navy, at this point in time, lost its big tract of land out there to the Pirates of Forrestal. That was one of the few times when land piracy has succeeded to undermine our Navy.

OSD finally awakened to the synthetic fuels business formally with the shale oil task group at about this point in time. We have synthetic fuels policy council which oversees that activity now. I show DOD/DOE had started here, actually it had started earlier. We and Brian Harney's people, this line should have been extended down, have had constructive interaction ever since to evaluate each others contract proposals and reports, and site visitations and all those sorts of things.

VG-3

Our view of the world is that if you start in say, 1980 and look out to the year 2020, problems of the costs, the problems of supply, and the inherent desire for secure resources, will force us to start switching over in military grade somewhere in this period. There will be overlap with commercial grades and, there will have to be simultaneous use but sometime in this period we will see extensive military use of synthetic fuels. Sometime out here depending on how this goes, and depending on the competition, we will probably see increasing use of synthetic fuels.

VG-4

The reason it is important to look way out in time is shown here. Each Weapons system is represented as a bar on this chart. You will notice here we are, 1980, we are beginning to retire weapons systems which we acquired in 1955. We keep our systems a very long time. In fact, if you ever travel to a dry section of the world, you will see old Mercedes Benz cars being driven by young taxi drivers. You say gee wiz, that taxi driver looks younger than the car. And you are probably right, they keep cars a very long time. If you look at our B-52 fleet, you will say the same thing. Most of our pilots are younger than the planes. And that is a remarkable thing to observe,

especially when a pilot flies the same plane as his father did some years ago. There are a number of cases of that sort being reported. We keep our planes a long time, we are presently designing them to use petroleum, and we are not going to retire that inventory just because we have a shift in fuel.

The first technology which we can bring on board with new technical content to account for synthetic fuels possibly could come in 1995, if we mount an accelerated program now, since it takes five years to get money and ten years to bring the program on line. So, we are talking about keeping petroleum based systems way out until 2015 and that's a consideration which is just a basis for everything else.

VG-5

If you are a program planner and you want to match the two previous schedules you see that you are going to, because of supply, have a transition in fuel from 1985 to 1995, but your system transition cannot take place until some other later epoch. You realize that all the pressure has to be put on the fuel to conform to the system which you already have. And so, when people come to us with all their great ideas about gasahol and liquid methanol and liquid hydrogen and you see all of that in the paper, please keep in mind that they are great ideas, but we have more pressing problems in the immediate future and those will be reserved for consideration as new technology way down stream after Hugh Guthrie is retired, in 1995.

VG-6

This is what a program looks like. You see the years here. These delta functions are spikes of fuel which we need to run the test programs. There are specific quantities. We have the first delta function, we are looking for the second and the third delta functions

out of the solicitation which is going out in a few weeks. After we are satisfied with that, and at the moment everything is success oriented, we have no reason to believe that this program will not be a success. But, considering the value of the equipment which we are putting at risk in this program we are taking the attitude that we want to go fast slowly. By 1983 or so, we will be ready to receive a constant rate, we say 10,000 barrels a day, for what we call operational validation. That means putting a few bases completely on this stuff and running the whole kit and kabootle and seeing what happens in the total energy environment. We understand that out in operational use, industry may supply this fuel as a blend. One blend here, another blend there, some other blend there, it may be blended refined product or it may be blended crude and then refined. We don't really know, but our attitude toward the early part of the program is that by testing on neat fuels, we have circumscribed as many of the parameters as we can understand and control and we will be as comfortable as we can be in facing whatever industrial scenario comes down stream. This is an important conceptual detail which had to be ironed out within the services. Exactly how can you test to anticipate everything that might come? And, remember, this is just fuels of J, lets say J means in this case JP-4 or JP-5 which is the Navy fuel or diesel Marine. For each fuel, you have to go through a satisfaction pattern of this sort. To eliminate the high costs of testing each of the multiple blends, we decided to test on neat fuels, do our operational validation on neat fuels, and procede with the assumption that everything will be alright.

VG-7

This is a picture which indicates the locations of Air Force activities which are prepared to consider the use of synthetic fuels. We have run through the Logistics, and all the other bureaucratic studies which have to be done to identify all of the parameters which will be accounted for in putting one or more of these bases on synthetic fuels.

Typically these bases all consume about 3 or 4 thousand barrels a day, which matches them up very nicely with modular programs, and many of them are within the range of the pipelines which exists right now. Some of the ones on the east coast are not, but we also have considered that any base which we put on synthetic fuels will have a sister base which is not on synthetic fuels which uses the same kind of aircraft and which can give us the kind of statistical control we need to understand what we are doing, both environmentally and in terms of logistics and system degradation.

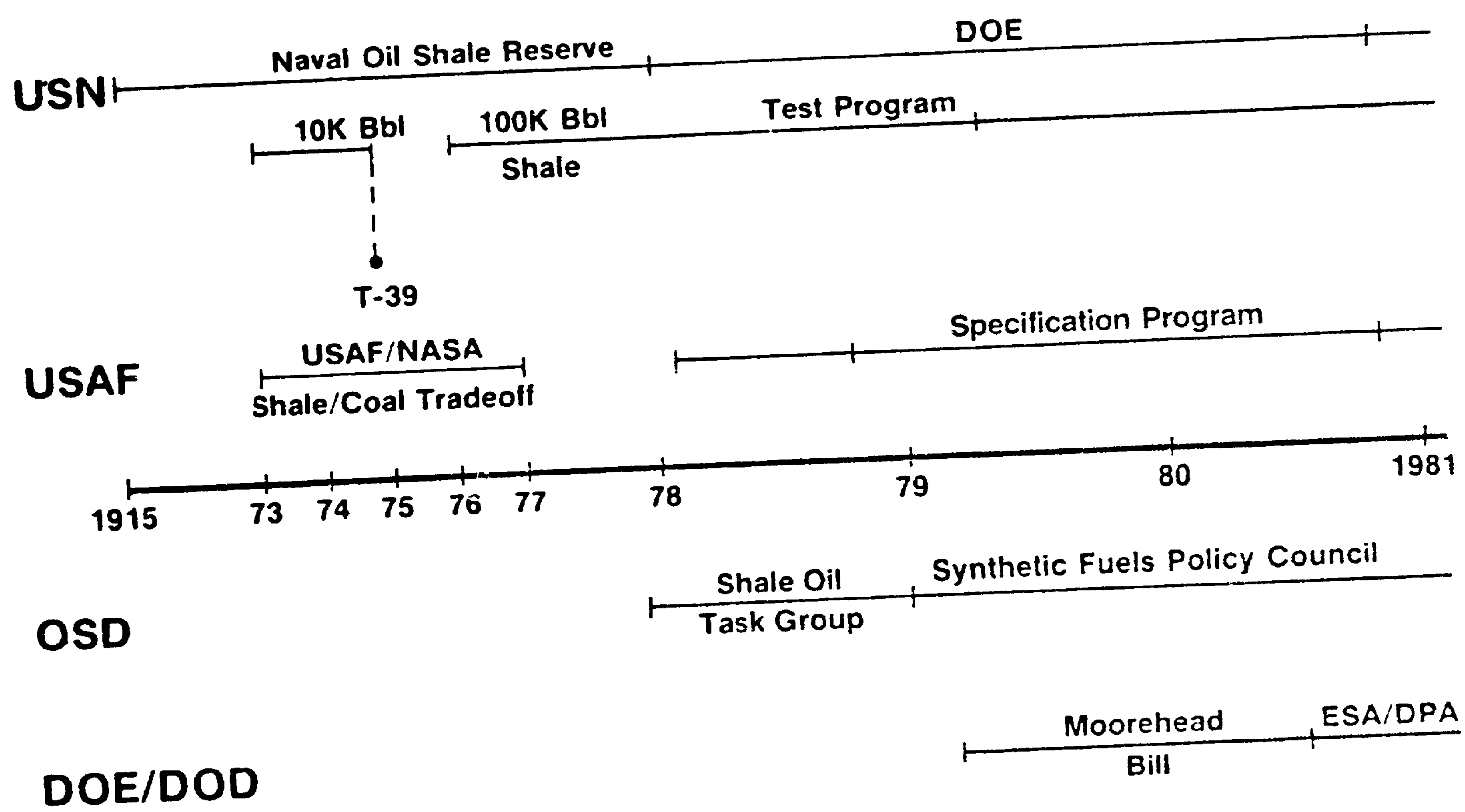
We had carried through all this planning and were at this point very early this year when everything came to a halt. As I said, it was a long weekend, we worked very hard to get to this point and then we came to a screetching halt. We are now waiting with baited breath for these DOE solicitations go out to learn of the locations where industry sees itself in a position to supply us. When we see that distribution of supply points we will then be able to pick and choose the bases where we want to use it. Certainly, we have enough opportunities and are in the best position of practically anyone in the country to do this kind of service. We are a highly technological customer and one who is very conscious of what our equipment is doing and of any problems which are likely to originate with the fuel.

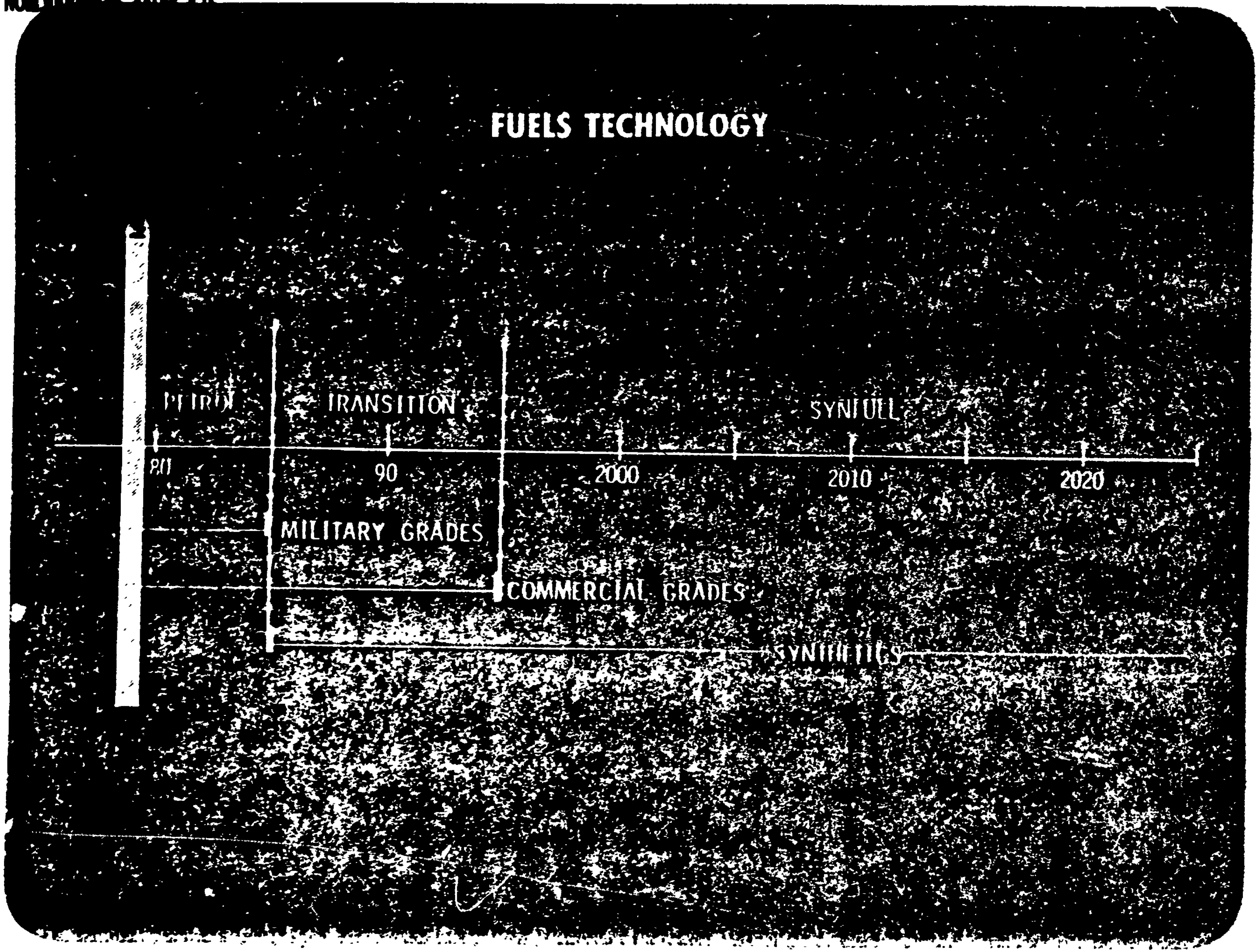
Thank you very much.

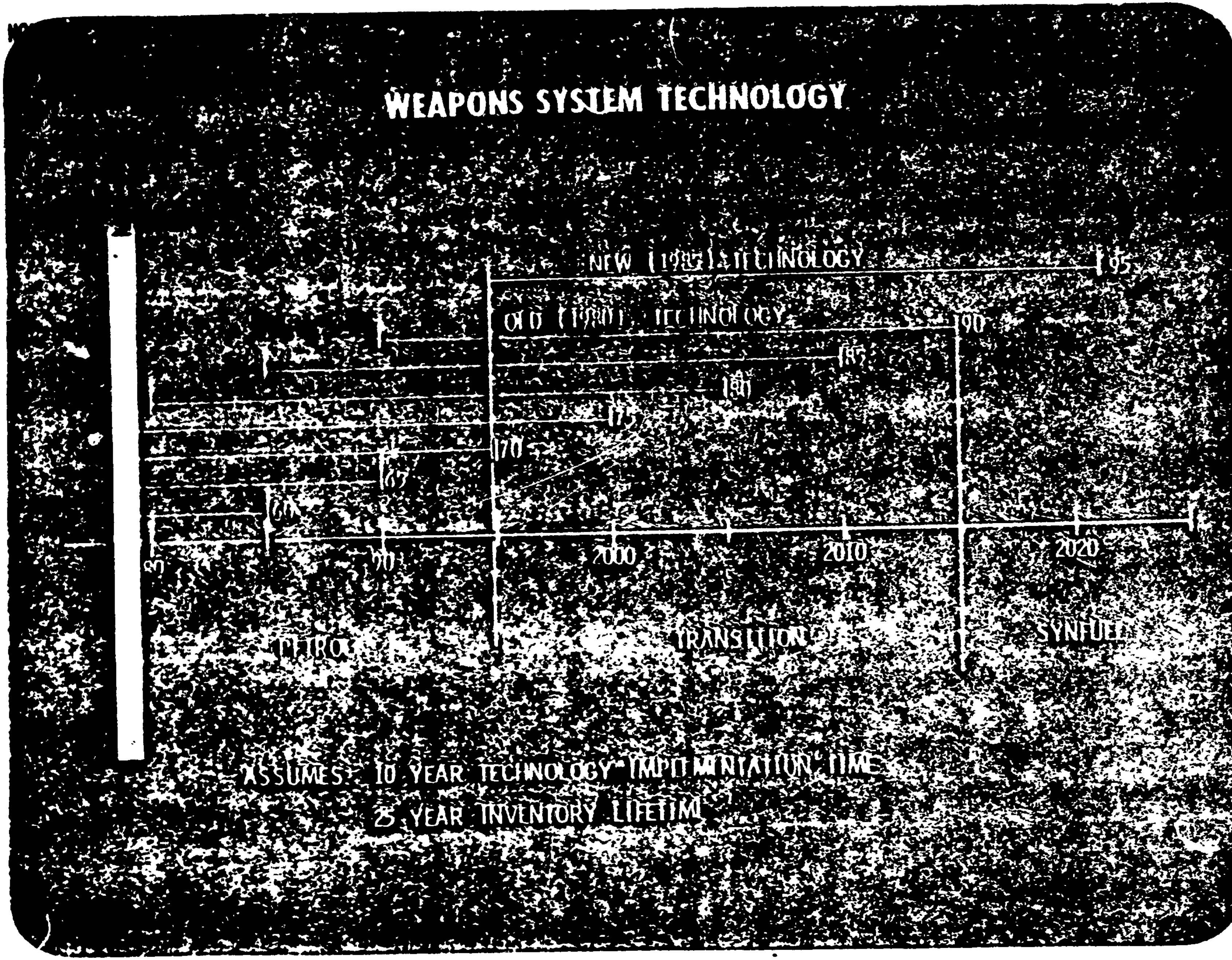
AREA	REQUIREMENTS (MILLION BBLS)	
	JP-4	JP-8
DOMESTIC		
- EAST/GULF COAST	35.4	0
- INLAND/WEST COAST	45.0	0
OVERSEAS		
- ATLANTIC/EUR/MED	5.5	2.7
- PACIFIC	8.8	0

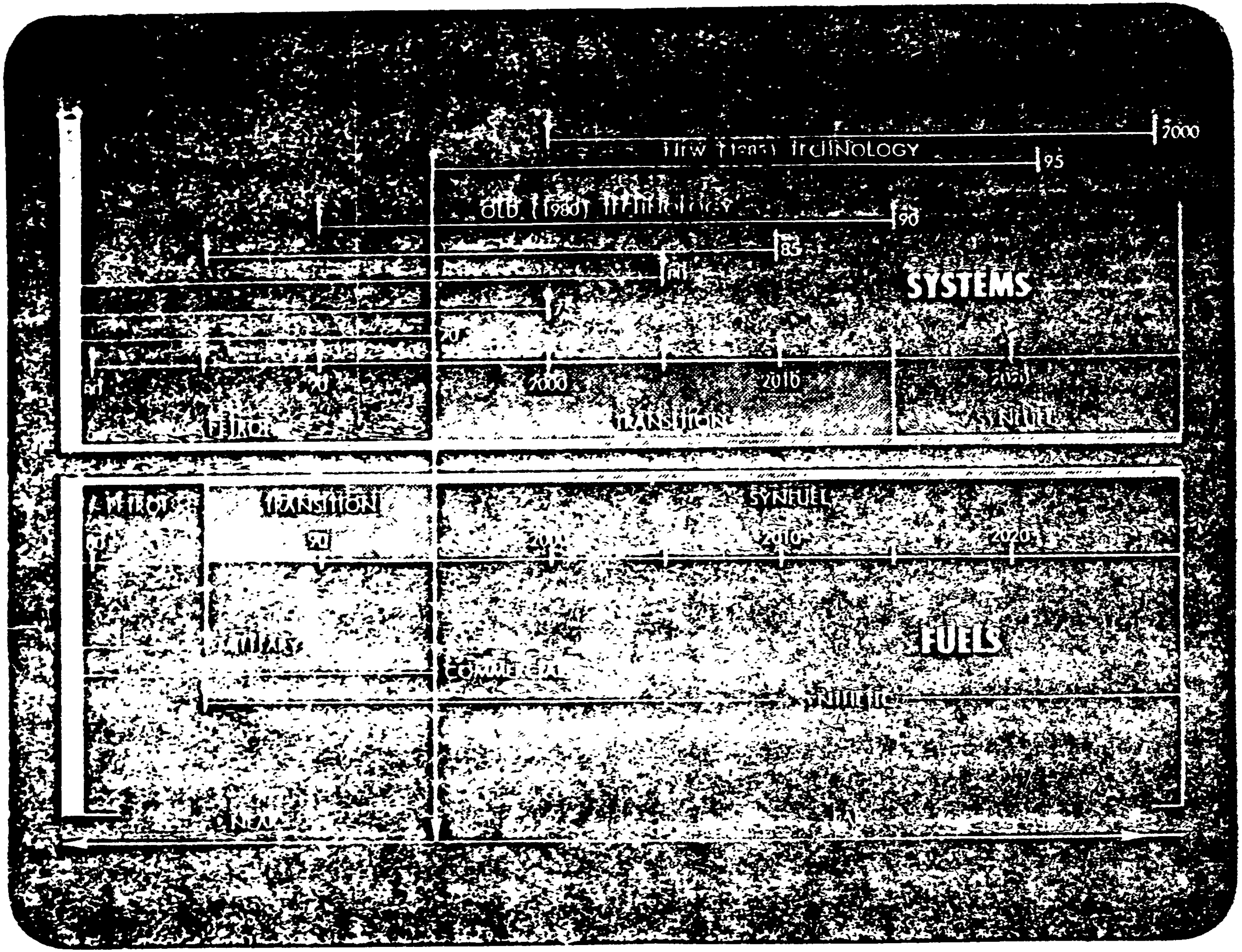
AIR FORCE REGIONAL FUEL REQUIREMENTS

History of DOD Synthetic Fuel Activity

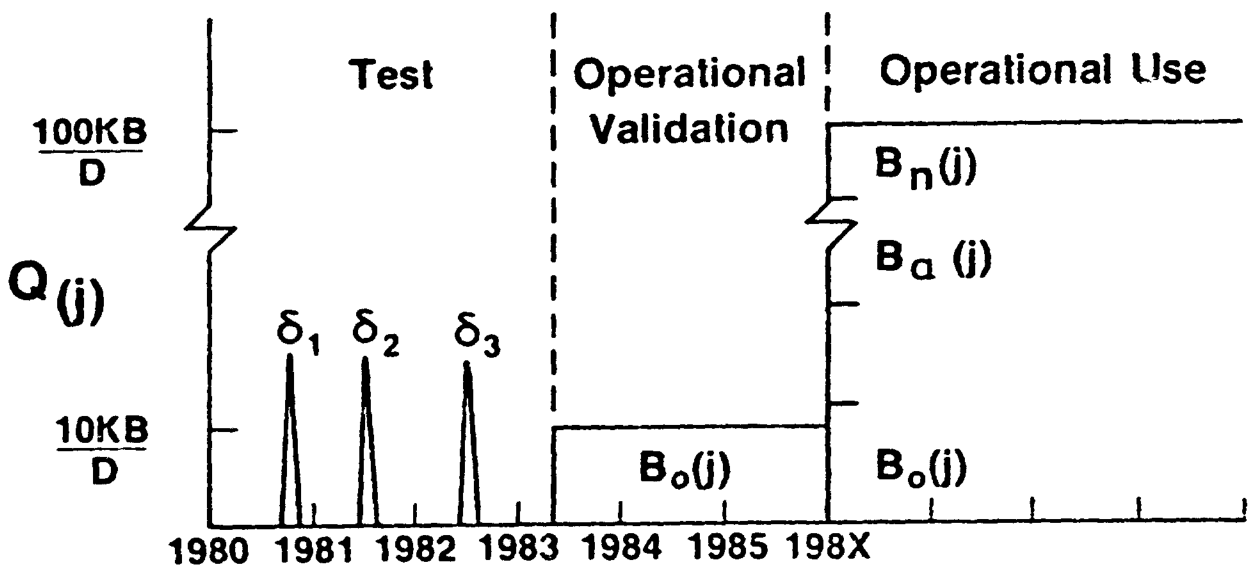



FUELS TECHNOLOGY
TRANSITION
SYNFUEL
90
2000
2010
2020
MILITARY GRADES
COMMERCIAL GRADES
SYNTHETICS


WEAPONS SYSTEM TECHNOLOGY
NEW (1985) TECHNOLOGY
OLD (1980) TECHNOLOGY
'95
'90
'85
'80
'75
'70
'65
'60
2000
2010
2020
PETRO
TRANSITION
SYNFUEL
ASSUMES: 10 YEAR TECHNOLOGY IMPLEMENTATION TIME
25 YEAR INVENTORY LIFETIME

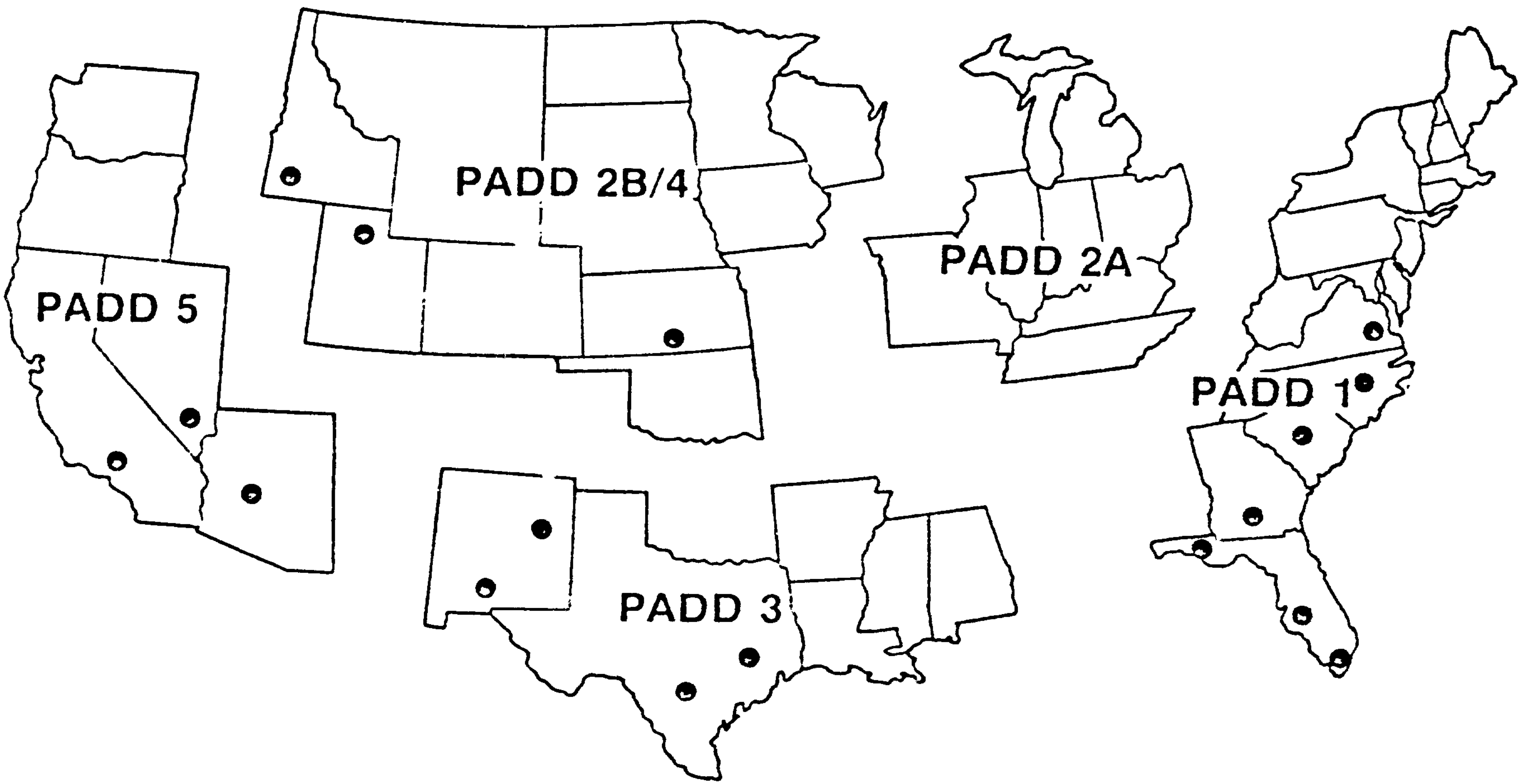

SYSTEMS
TRANSITION
SYNFUEL
FUELS
TRANSITION
SYNFUEL
COMMERCIAL
2000
2010
2020
95
90
85

Requirement Profile — Fuel(j)



(j) = Fuel Specification (JP-4, JP-5, DFM, . . .)
α = Synthetic Blend

Potential Operational Validation Location (JP-4)



NASA FUELS PROGRAMS

Richard A. Rudey
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

SUMMARY

NASA is conducting a wide-ranging program with the objective of identifying the characteristics of fuels for future jet aircraft, assessing the impact of these fuel characteristics on both engine and aircraft technology and evaluating the capability of current and advanced technology to minimize or eliminate any adverse effects that would occur if these fuel characteristics differ from those of current Jet-A specification fuel. The current overall NASA program, although primarily focused on ambient temperature liquid hydrocarbon fuels, also includes some activities related to cryogenic fuels; i.e., liquid methane and hydrogen. The program structure is composed of three main elements; identification of future fuels, fuel system R&T for broadened-property fuels, and combustion R&T for broadened-property fuels and two supporting elements; fuels and combustion fundamentals, and systems analysis and trade-off studies. The R&T being pursued is primarily generic in nature, as indicated by the description of various program element tasks and examples of results shown on the figures, but also includes focused R&T efforts such as the Broad-Specification Fuels Program. The program, as it is currently being conducted, will identify and evaluate the capability of advanced technologies to use flexible fuel properties and will provide guidance regarding the impact of varying fuel properties to both the producer and user communities, to ASTM fuel specification committees and to government agencies concerned with environmental impact. The results to date have been encouraging and knowledge that is being obtained and will continue to be obtained will provide a sound basis for defining and selecting future options regarding trade-offs between fuel properties and aircraft/engine technology.

POTENTIAL ALTERNATIVES

ALTERNATIVES	ADVANTAGES	DISADVANTAGES
PRODUCE SPECIFICATION JET FUEL	OPTIMIZED FUEL PROPERTIES FUEL RELATED AIRCRAFT/ENGINE MODIFICATIONS NOT REQUIRED	POTENTIAL SHORTAGES POTENTIAL INCREASES IN REFINERY ENERGY CONSUMPTION POTENTIALLY HIGHER AIRCRAFT OPERATING COST
ALLOW VARIATIONS IN JET FUEL PROPERTIES	COULD PROVIDE FLEXIBLE AND RELIABLE SUPPLY COULD MINIMIZE REFINERY ENERGY CONSUMPTION COULD MINIMIZE AIRCRAFT OPERATING COST	POSSIBLE ADVERSE EFFECTS ON AIRCRAFT/ENGINE LIFE, PERFORMANCE AND EXHAUST EMISSIONS

CS-80-4304

FIGURE 1

NASA RESEARCH AND TECHNOLOGY FOR FUTURE JET FUELS

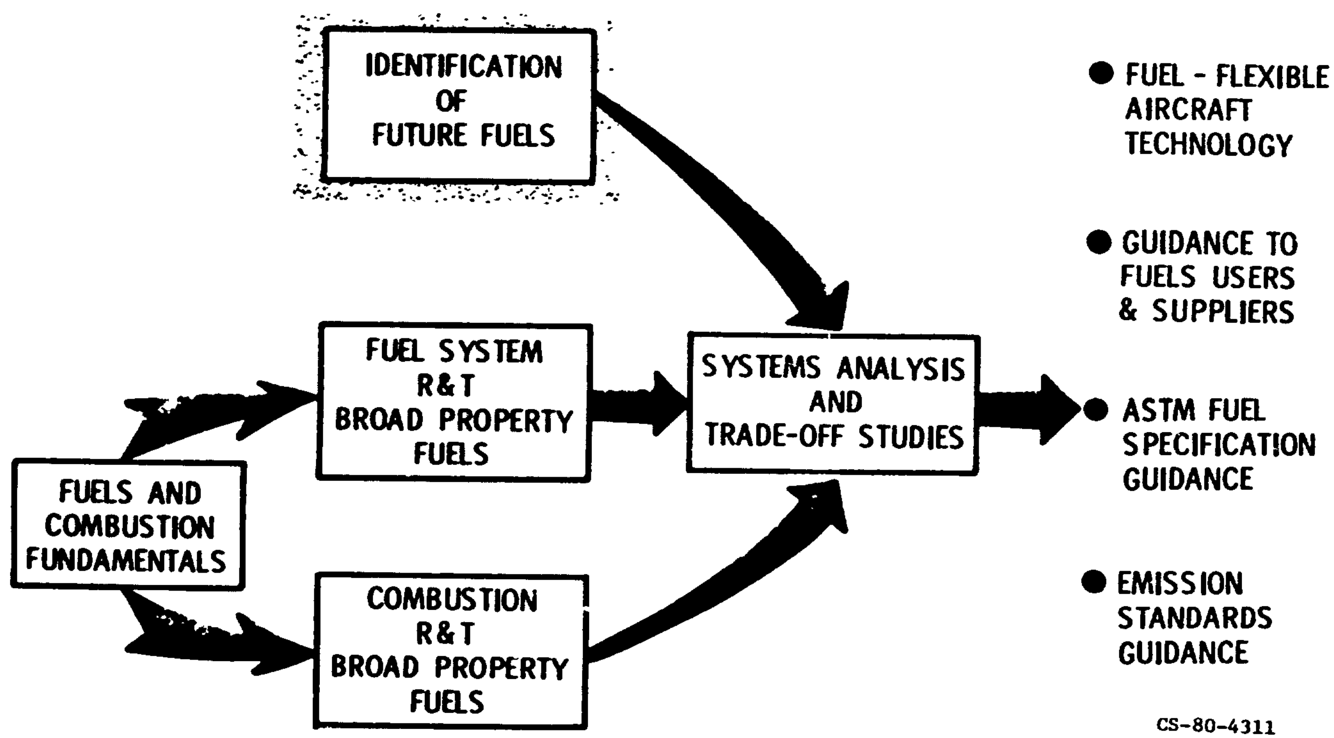


FIGURE 2

IDENTIFICATION OF FUTURE JET FUELS

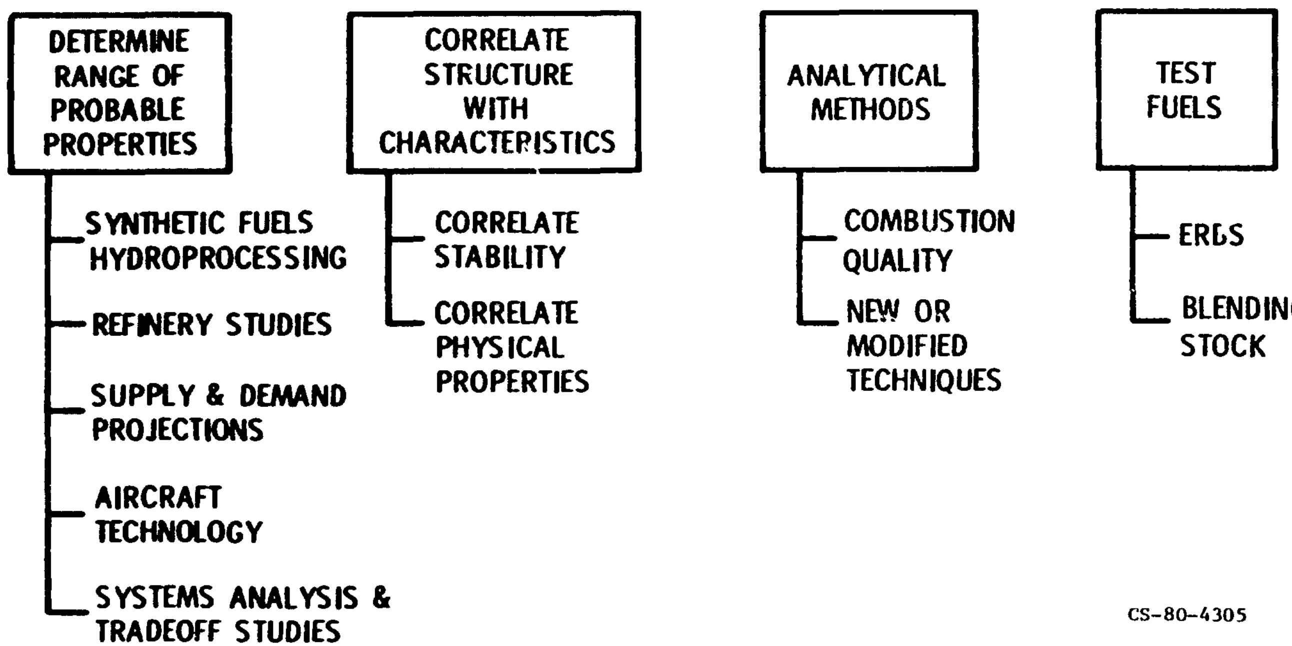


FIGURE 3

POTENTIAL CHARACTERISTICS OF FUTURE JET FUELS

CHARACTERISTIC	CURRENT JET A	FUTURE BROADENED-PROPERTIES FUELS
COMPOSITION:		
AROMATICS, vol %	17-25	25-40
HYDROGEN, wt %	13.5-14.0	12-13.5
SULFUR, wt %	0.01-0.1	~0.3
NITROGEN, ppm	<10	50-2000
VOLATILITY:		
FLASH POINT, ^{o}C	38-66	38-66
BOILING RANGE, ^{o}C	171-277	171-343
FLUIDITY:		
FREEZING POINT, ^{o}C	-46 TO -40	-34 TO -18
VISCOSITY, cs AT -23^{o} C	~5	~12
HEAT OF COMBUSTION:		
MJ/kg	42.80-43.26	41.87-42.80
THERMAL STABILITY:		
BREAKPOINT TEMP, ^{o}C	≥260	?

CS-80-4310

FIGURE 4

NASA RESEARCH AND TECHNOLOGY FOR FUTURE JET FUELS

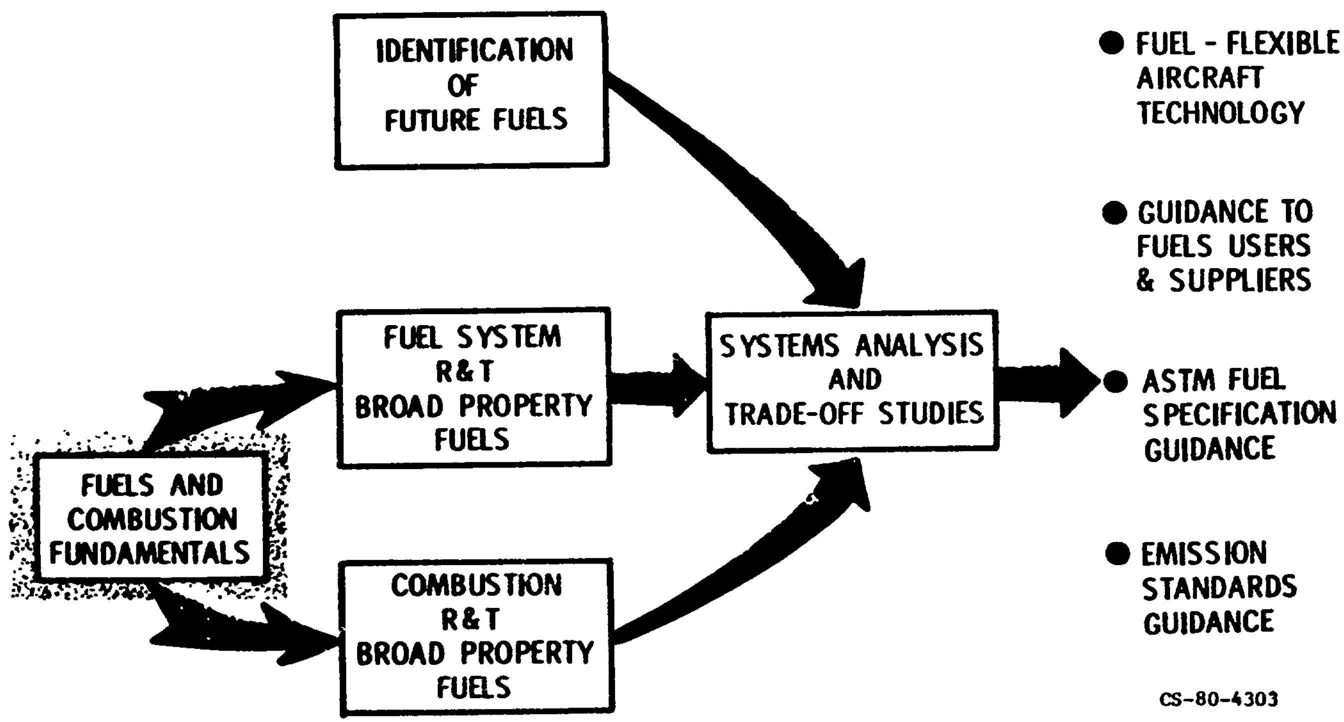


FIGURE 5

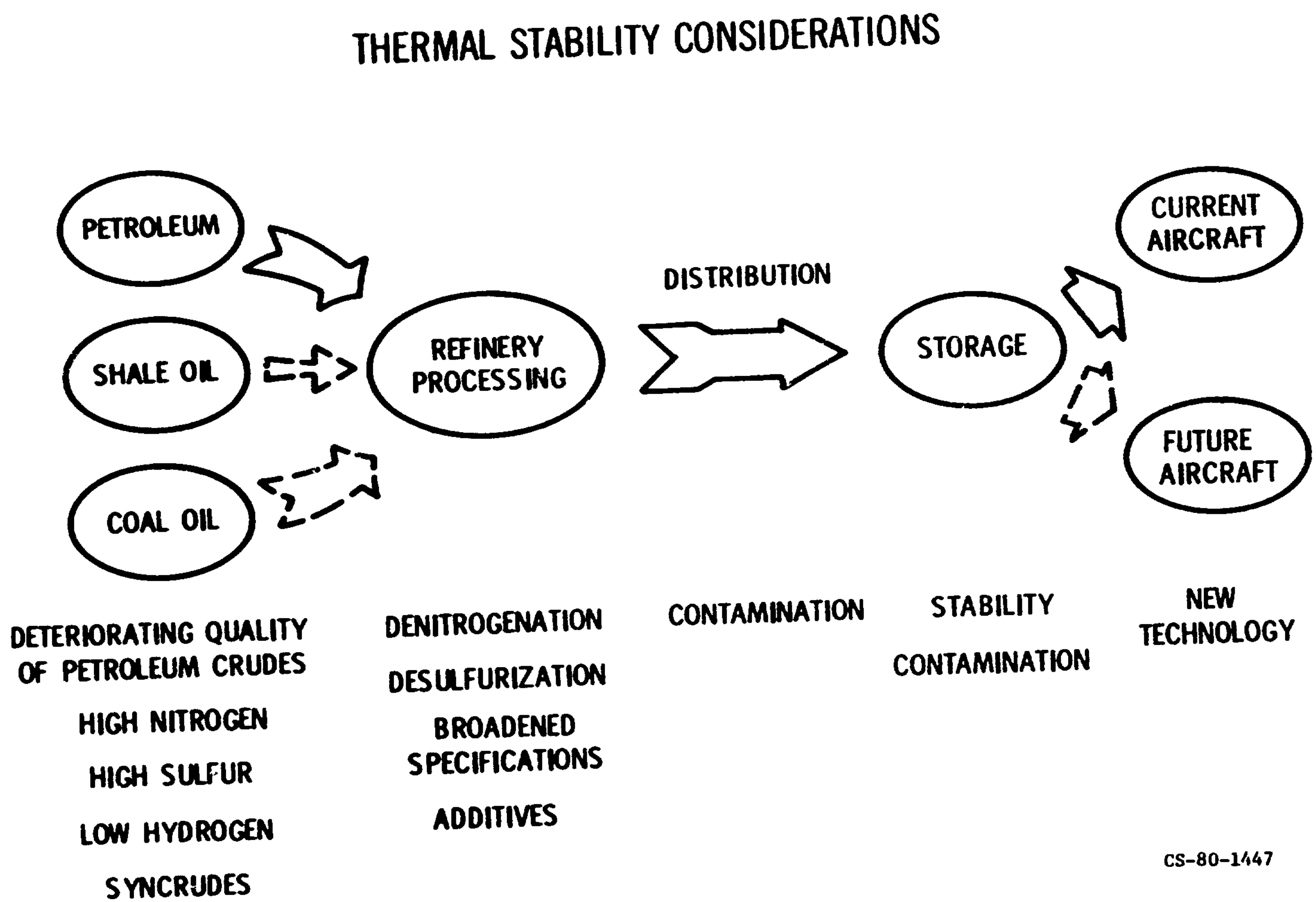

THERMAL STABILITY CONSIDERATIONS
PETROLEUM
SHALE OIL
COAL OIL
REFINERY PROCESSING
DISTRIBUTION
STORAGE
CURRENT AIRCRAFT
FUTURE AIRCRAFT
DETERIORATING QUALITY OF PETROLEUM CRUDES
HIGH NITROGEN
HIGH SULFUR
LOW HYDROGEN
SYNCRUDES
DENITROGENATION
DESULFURIZATION
BROADENED SPECIFICATIONS
ADDITIVES
CONTAMINATION
STABILITY
CONTAMINATION
NEW TECHNOLOGY
CS-80-1447

FIGURE 6

NASA RESEARCH AND TECHNOLOGY FOR FUTURE JET FUELS

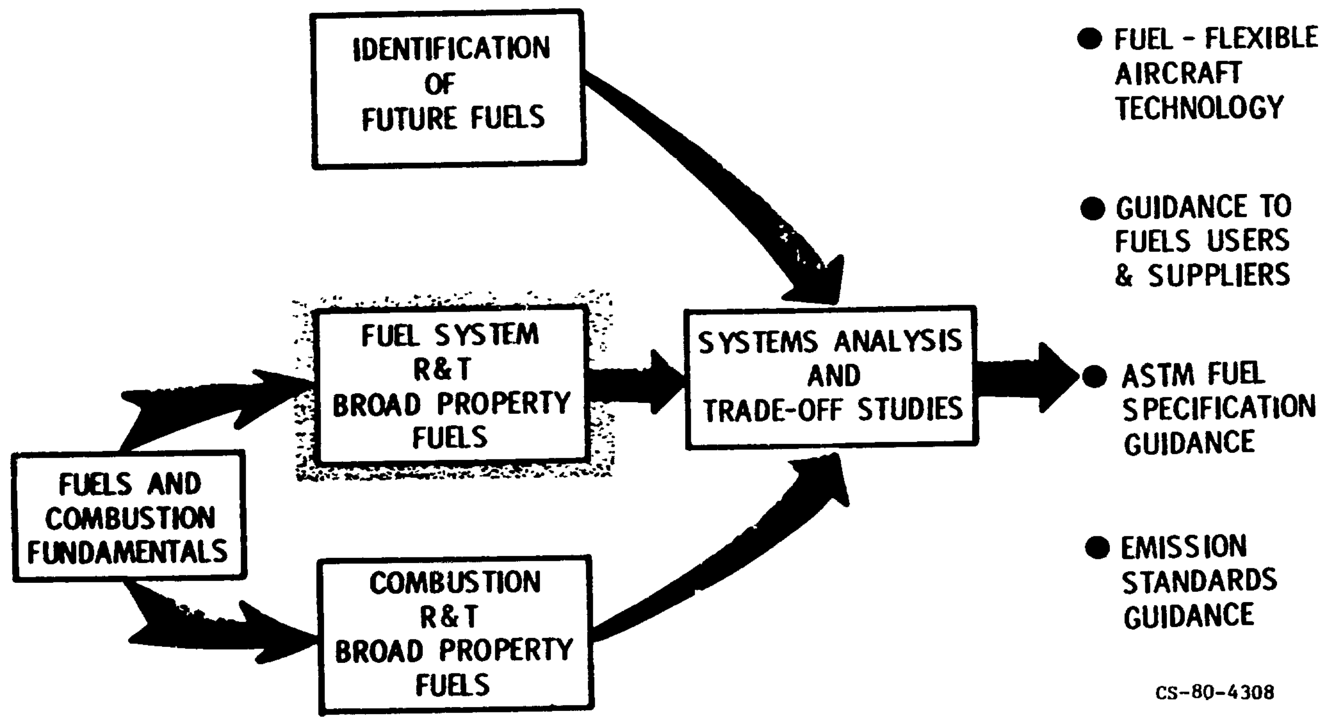


FIGURE 7

FUEL SYSTEMS RESEARCH AND TECHNOLOGY

JET FUEL PROPERTY	R & T FOCUS
WATER SOL AND CLEANLINESS	TRENDS WITH FUEL COMPOSITION
FLASH POINT	SAFETY
VISCOSITY	LOW TEMPERATURE BEHAVIOR
AROMATIC CONTENT	MATERIAL COMPATIBILITY
FREEZING POINT	ANALYSIS OF IN-FLIGHT TEMPERATURES
	DESIGN OF SYSTEM MOD. FOR HIGH F. P.
	EXPERIMENTAL STUDY OF LOW TEMP PUMPABILITY
	FULL-SCALE WING TANK SIMULATOR
	RAPID FREEZING PT MEASUREMENT METHOD

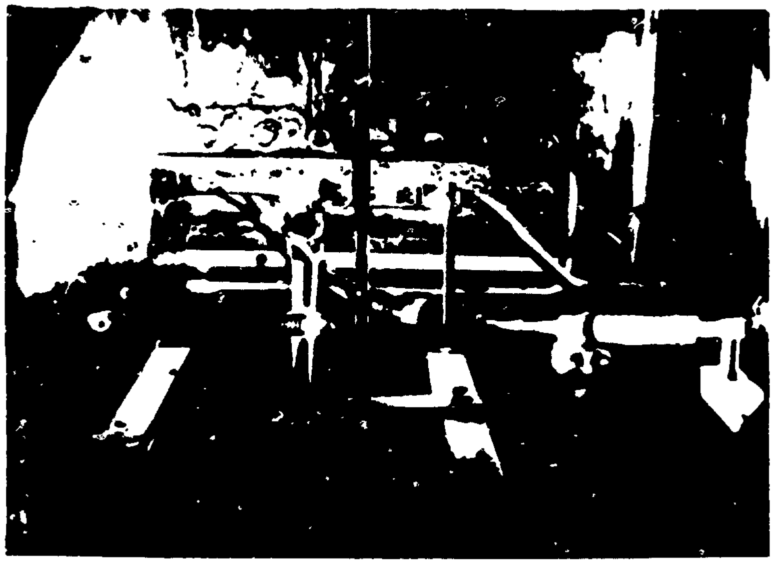
CS-80-4299

FIGURE 8

LOW TEMPERATURE FUEL SYSTEM STUDY (LOCKHEED)

OBJECTIVES:

- EXPERIMENTAL STUDY OF PUMPABILITY AND TWO-PHASE FLOW OF AVIATION FUELS AT LOW TEMPERATURES
- CORRELATION OF FUEL SYSTEM PUMPABILITY WITH LAB FREEZING POINT MEASUREMENT



INTERIOR OF FUEL TANK SIMULATOR FILLED WITH JET A (TYPICAL OF 1011 WING TANK SECTION).

END OF PUMPOUT TEST WITH JET A AFTER 7-HOUR COOLDOWN. FUEL SLUSH IS NOT PUMPABLE.

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CD-12290-23

FIGURE 9

NAS.. RESEARCH AND TECHNOLOGY FOR FUTURE JET FUELS

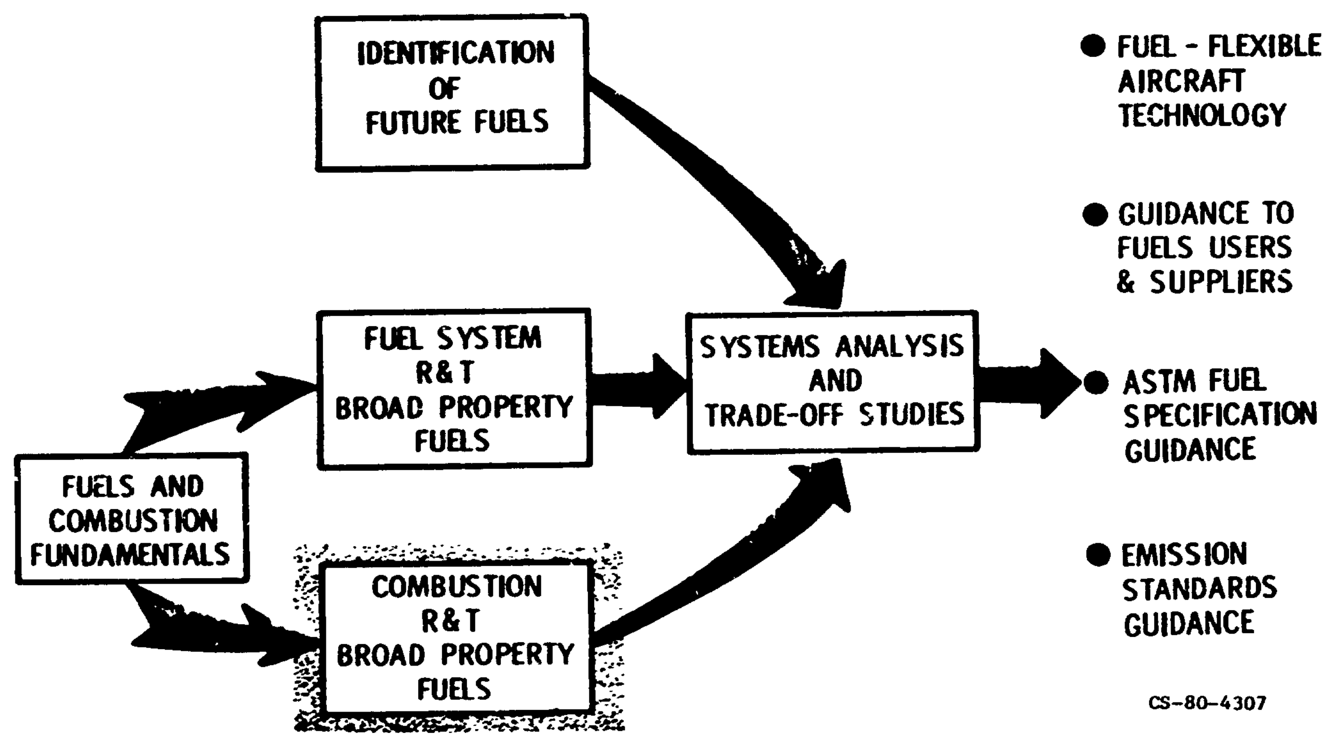


FIGURE 10

FUELS / COMBUSTION RESEARCH AND TECHNOLOGY

COMBUSTORS/ENGINES	OBJECTIVE	EMPHASIS
IN-SERVICE	ASSESS SENSITIVITY TO FUEL PROPERTY VARIATIONS	EXAMINE PERFORMANCE WITH BROADENED PROPERTY FUELS
IN-SERVICE	PROVIDE LIMITED FUEL FLEXIBILITY	SUBCOMPONENT TECHNOLOGY
NEW CONCEPTS	ESTABLISH OPTIMUM FUEL FLEXIBILITY CAPABILITIES	EVOLVE ADVANCED COMBUSTION TECHNOLOGY

CS-80-4300

FIGURE 11

FUELS/COMBUSTION RESEARCH AND TECHNOLOGY PROGRAMS

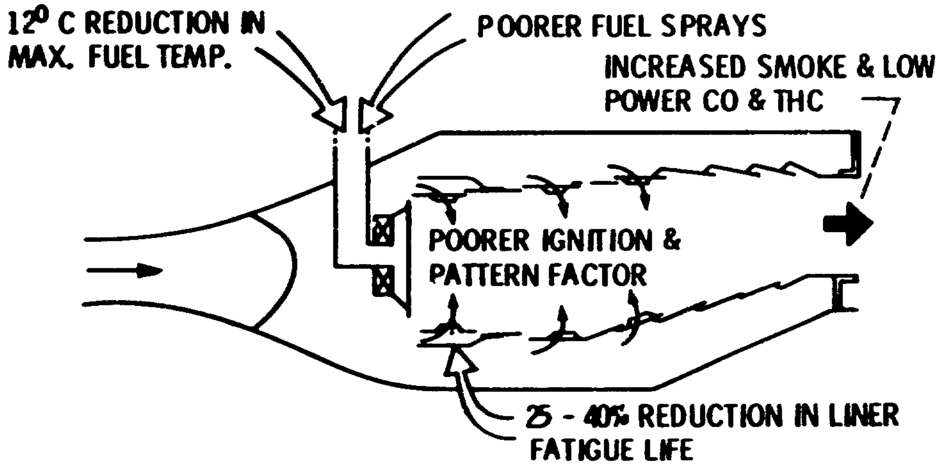
ORGANIZATION	APPLICATION	PROGRAMS
DOD AIR FORCE WRIGHT AERONAUTICAL LABORATORY	MILITARY AVIATION	• JT9, F101 • FUEL-MAIN BURNER /TURBINE EFFECTS
	JOINT EFFORT	
NASA-LeRC	CIVIL AVIATION	• ANALYTICAL STUDIES • EXP COMB. STUDY • COMB. TECHNOLOGY
	COMBINED EFFORT	
DOE FOSSIL ENERGY DIVISION	STATIONARY POWER	• LOW NO_x HEAVY FUEL COMBUSTOR • SYNFUEL CHARACTERIZATION AND COMBUSTION STUDIES

CS-80-4309

FIGURE 12

ANALYTICAL STUDY RESULTS

IN CONVENTIONAL COMBUSTORS THE USE OF BROAD PROPERTY FUELS COULD RESULT IN:



FUEL EFFECTS COULD BE MINIMIZED BY MULTI-ZONE, LEAN BURNING COMBUSTORS

CS-80-1321

FIGURE 13

EFFECT OF HYDROGEN CONTENT OF FUEL ON LINER TEMPERATURE

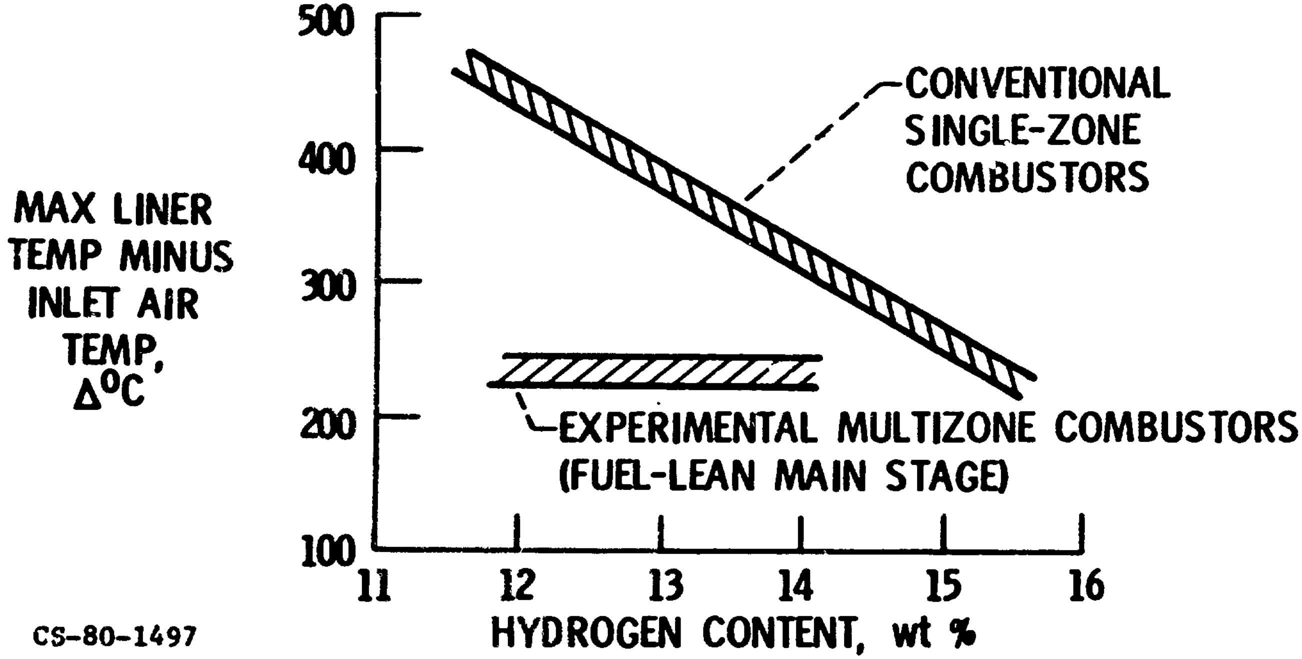


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FIGURE 14

NASA BROAD-SPECIFICATION FUELS COMBUSTION TECHNOLOGY PROGRAM

PROGRAM OBJECTIVE

1. TO EVOLVE AND DEMONSTRATE THE TECHNOLOGY REQUIRED TO ENABLE CURRENT AND NEXT-GENERATION HIGH-THRUST, HIGH-BYPASS-RATIO TURBOFAN ENGINES TO UTILIZE BROAD-PROPERTIES FUELS.

2. TO VERIFY THE EVOLVED TECHNOLOGY IN FULL-SCALE ENGINE TESTS.

PLANNED PROGRAM SCHEDULE

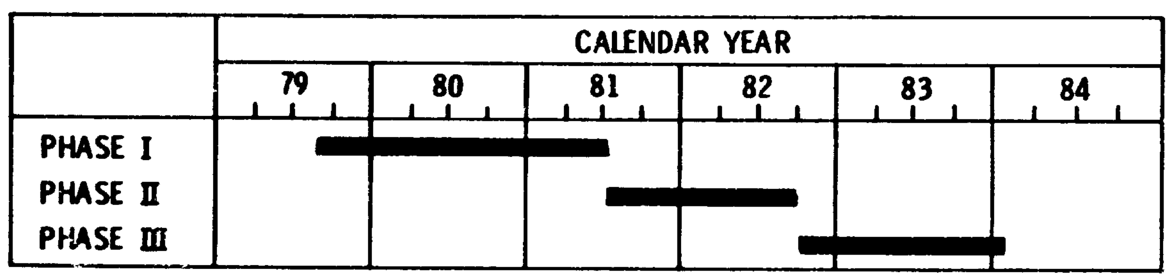

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FIGURE 15

NASA RESEARCH AND TECHNOLOGY FOR FUTURE JET FUELS

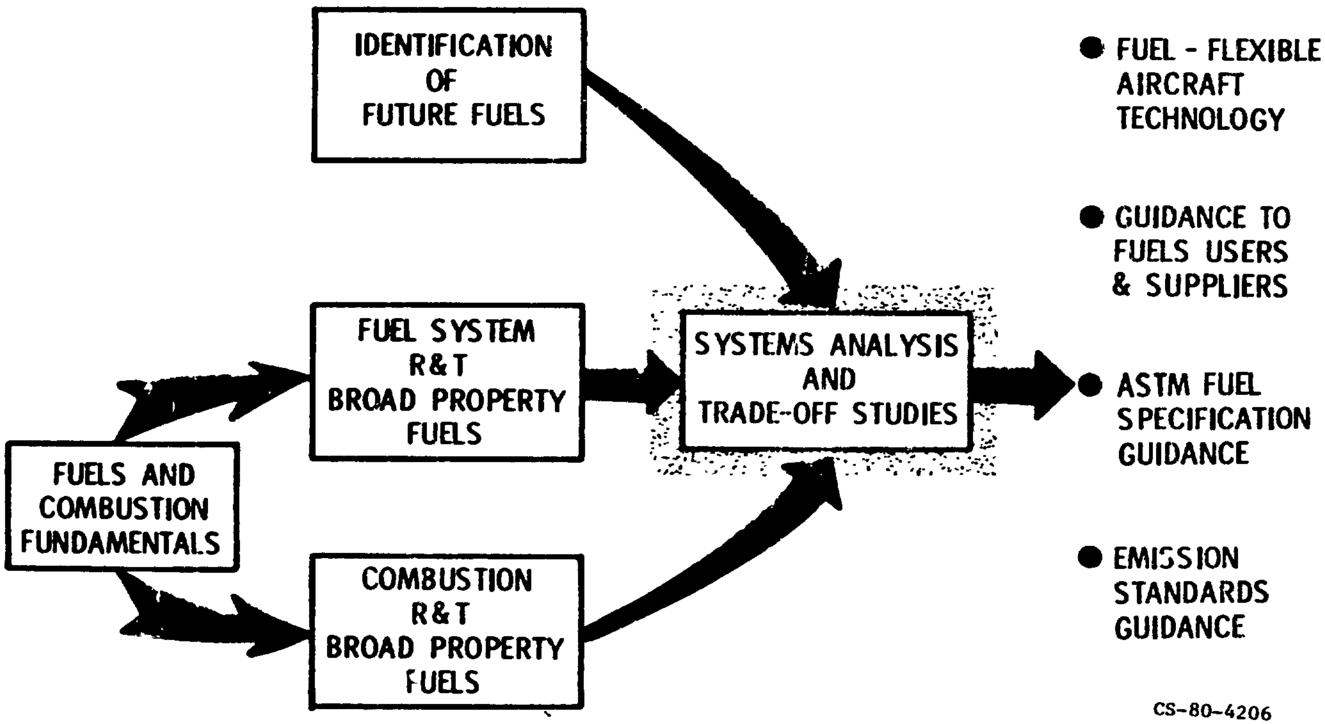


FIGURE 16

Impacts Of Broadened-Specification Fuels On Aircraft Turbine Engine Combustors

D. W. BAHR
GENERAL ELECTRIC COMPANY
AIRCRAFT ENGINE GROUP
CINCINNATI, OHIO

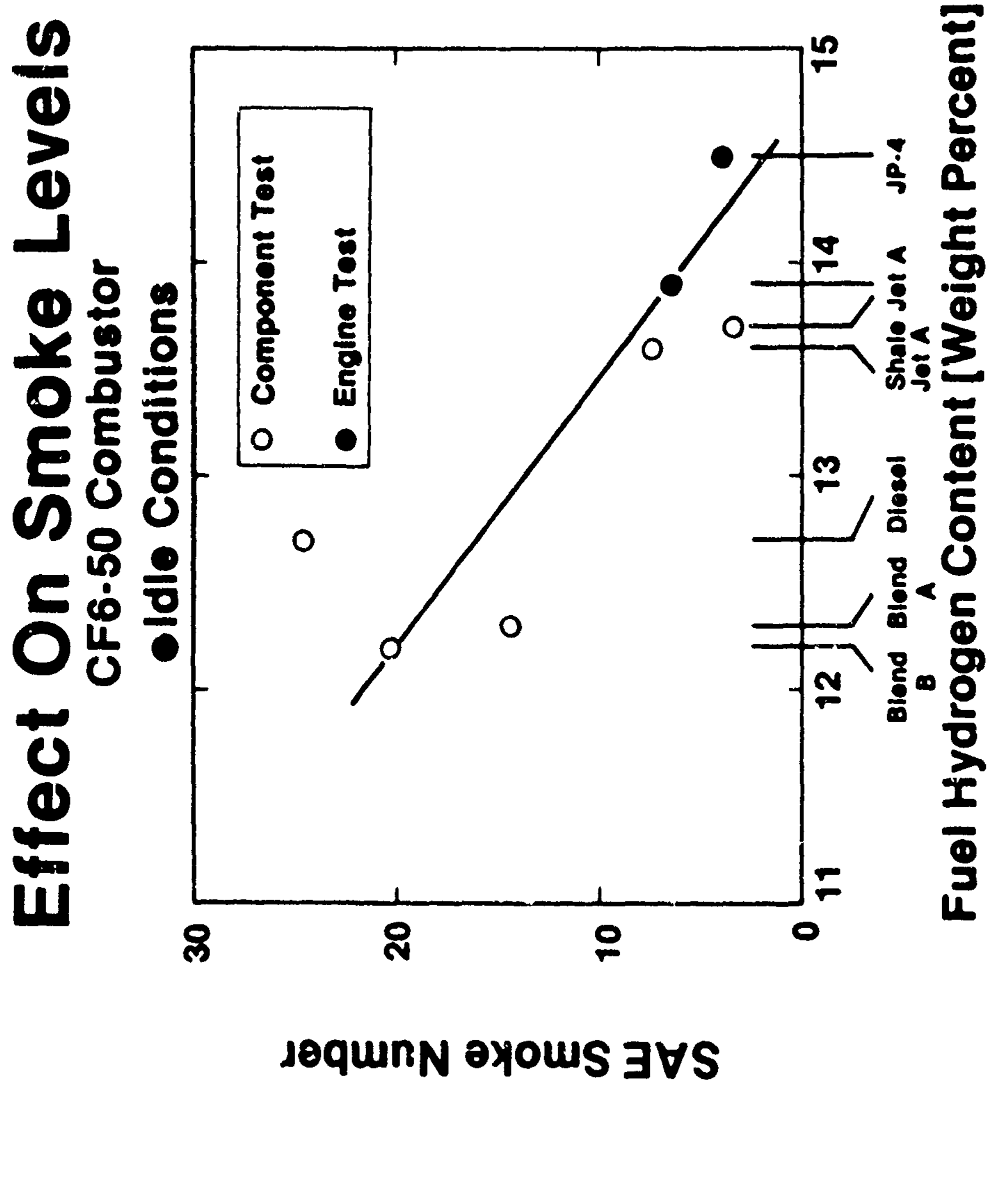
Typical Broadened Specification For Jet A

	Jet A Typical	Jet A Specification	ERBS*
● Composition			
· Aromatic Content [Vol %]	18.0	25.0 [Max]	---
· Hydrogen Content [Wt %]	13.8	---	12.8 [Min]
● Volatility			
· Distillation [K]			
10 %	466	478 [Max]	478 [Max]
FBP	533	572 [Max]	589 [Max]
● Fluidity			
· Freezing Point [K]	228	233 [Max]	244 [Max]
· Viscosity [mm^2/s]			
At 244 K	6	8 [Max]	---
At 250 K	---	---	12 [Max]
● Thermal Stability			
· JFTOT Breakpoint Temperature [K]	Above 533	533 [Min]	511 [Min]

* EXPERIMENTAL REFEREE BROAD-SPECIFICATION

Possible Impacts

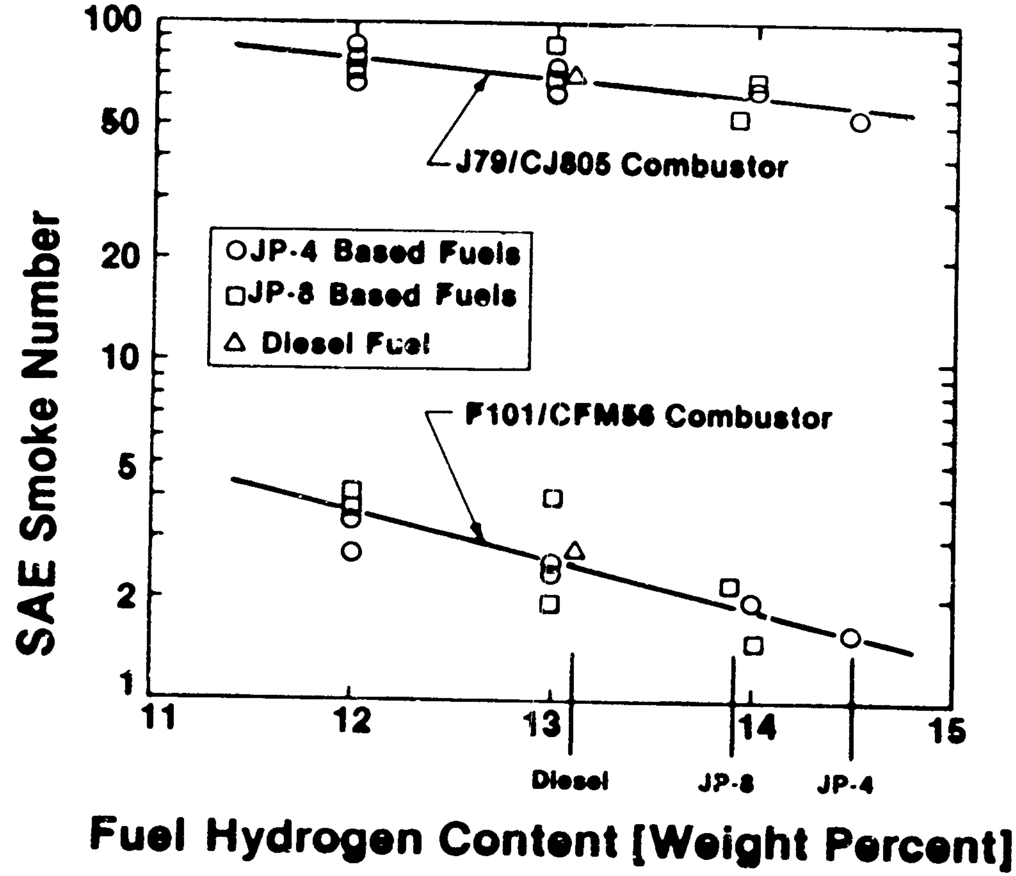
Effect	Impact
• Decreased Hydrogen Content [Increased Aromatic Content]	
· Increased Smoke Levels	· Increased Exhaust Visibility
· Increased Flame Radiation	· Increased Combustor/Turbine Metal Temperatures
· Increased Carbon Formation/Deposition	· Increased Combustor Hot Streaking/Pattern Factors · Increased Turbine Erosion
· Increased NO_x Levels	· Increased NO_x Emissions
• Decreased Fuel Volatility/Fluidity	· Decreased Engine Starting/ Relight Capabilities · Increased CO/HC Levels
• Decreased Thermal Stability	· Increased Fuel Injector Plugging



Effect On Smoke Levels
CF6-50 Combustor
●Idle Conditions
SAE Smoke Number
30
20
10
0
11
12
13
14
15
○ Component Test
● Engine Test
Blend B
Blend A
Diesel
Shale Jet A
Jet A
JP-4
Fuel Hydrogen Content [Weight Percent]

Effect On Smoke Levels

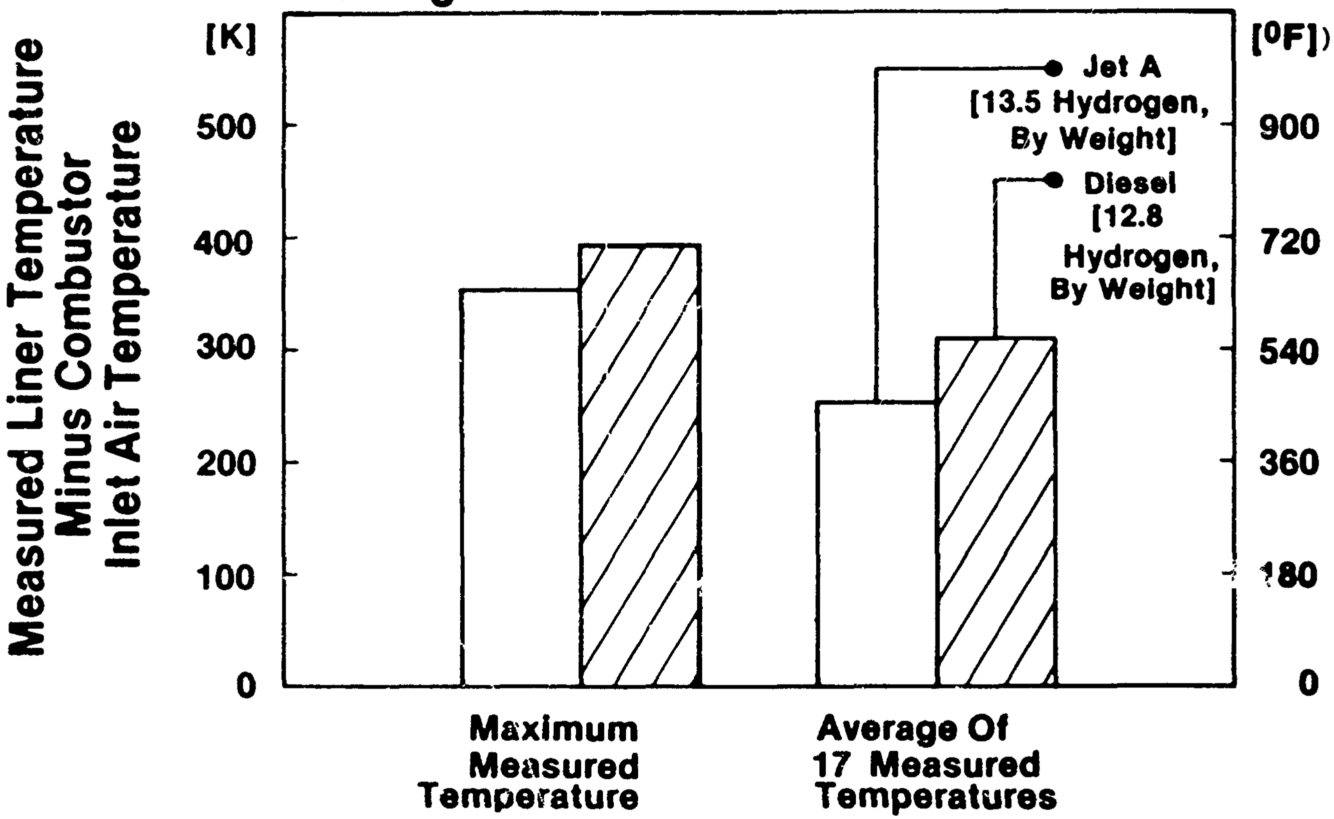
● Component Tests ● Takeoff Conditions



Effect On Liner Temperatures

CF6-6 Combustor

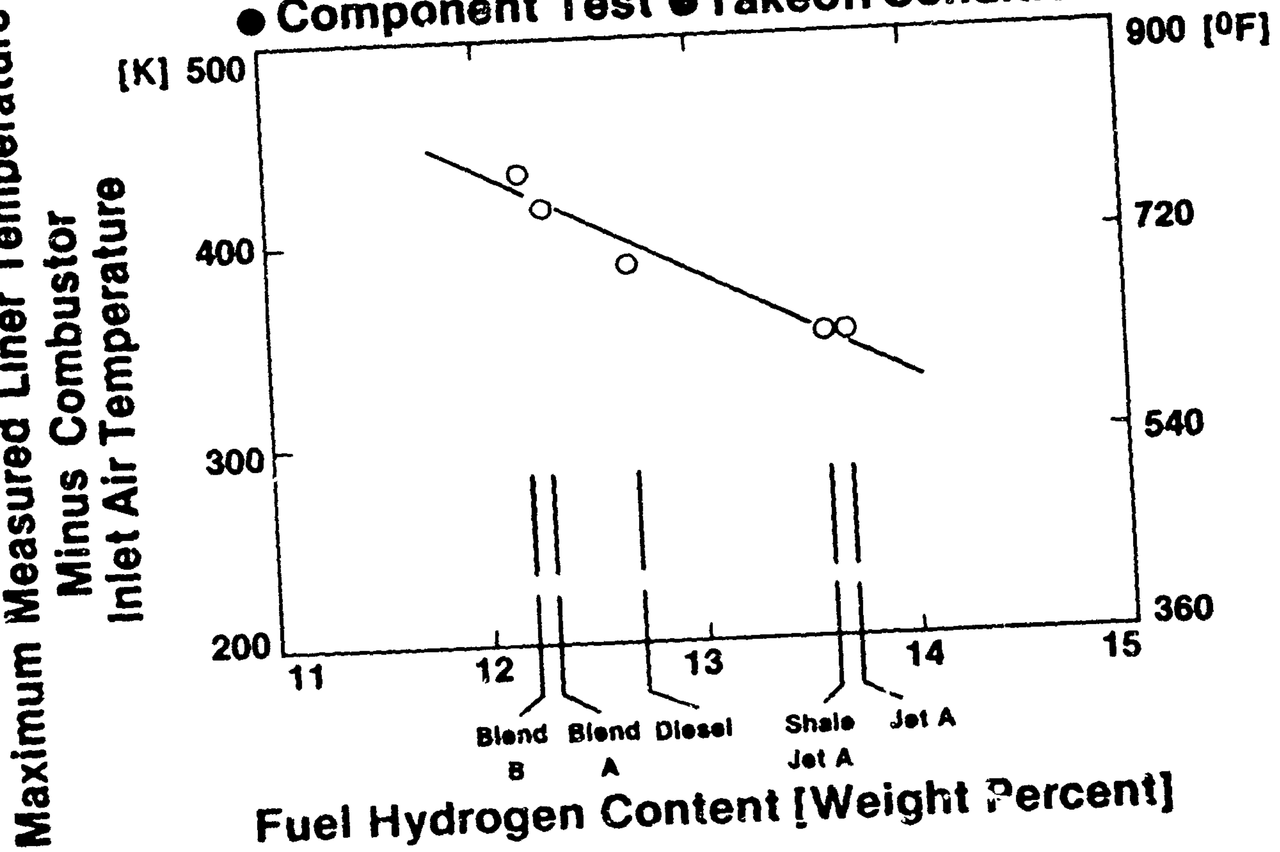
● Engine Test ● Climbout Conditions



Effect On Liner Temperatures

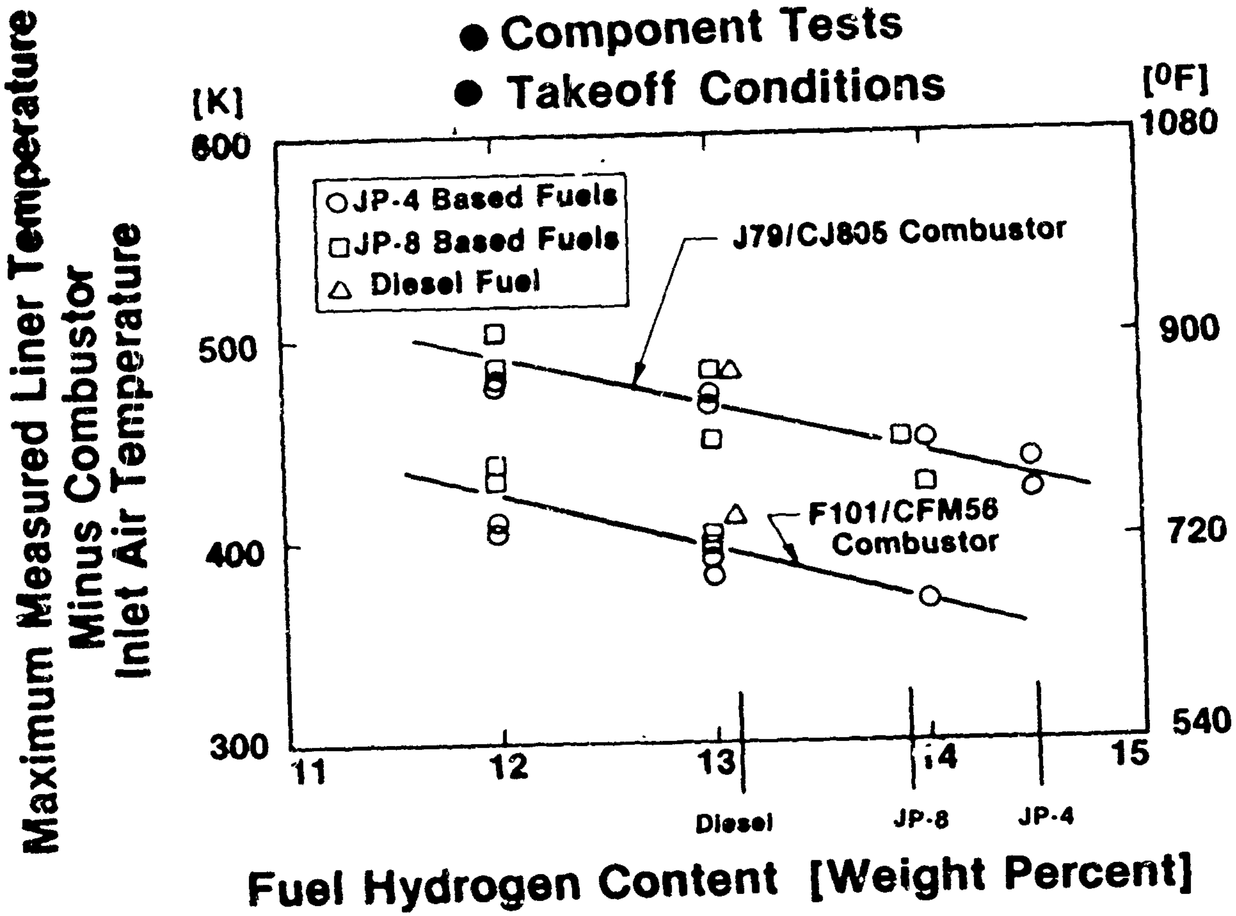
CF6-50 Combustor

● Component Test ● Takeoff Conditions



Effect On Liner Temperatures

- Component Tests
- Takeoff Conditions



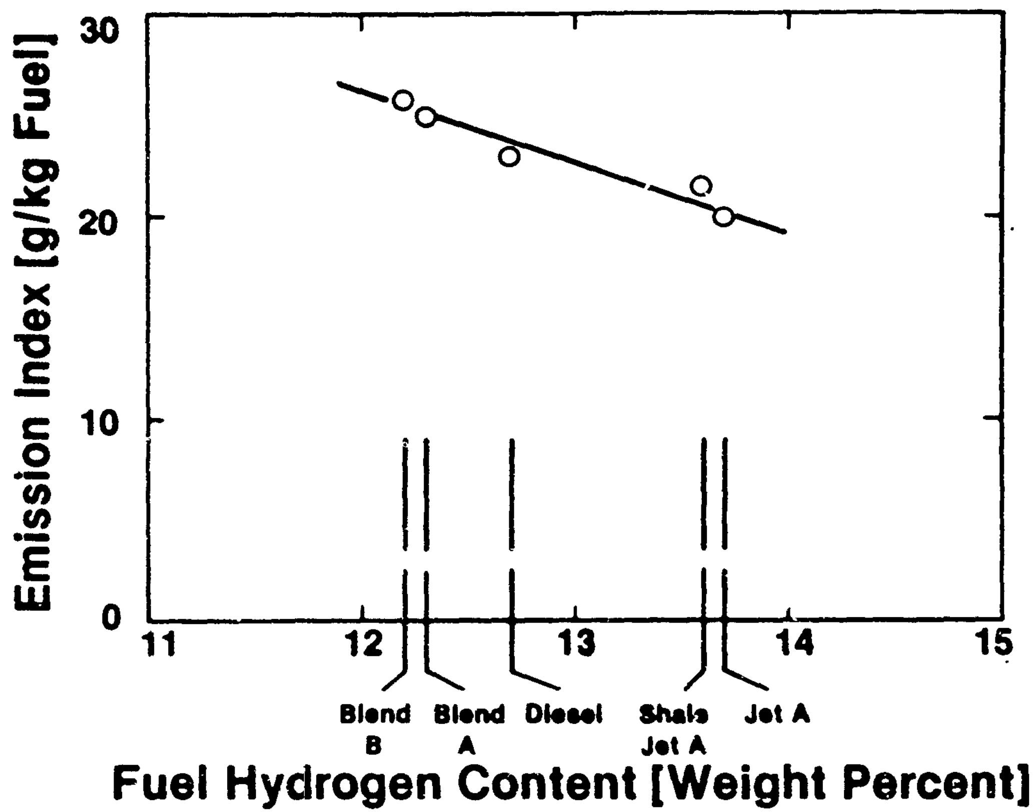
Predicted Effect On Liner Life

Fuel Hydrogen Content [Wt %]	Relative Combustor Liner Life	
	J79/CJ805	F101/CFM56
14.5 [Current JP-4]	1.28	1.39
13.8 [Current Jet A/JP-8/JP-5]	1.00	1.00
12.8 [ERBS]	0.67	0.72
12.0 [Coal-Derived]	0.45	0.65

Effect On NO_X Levels

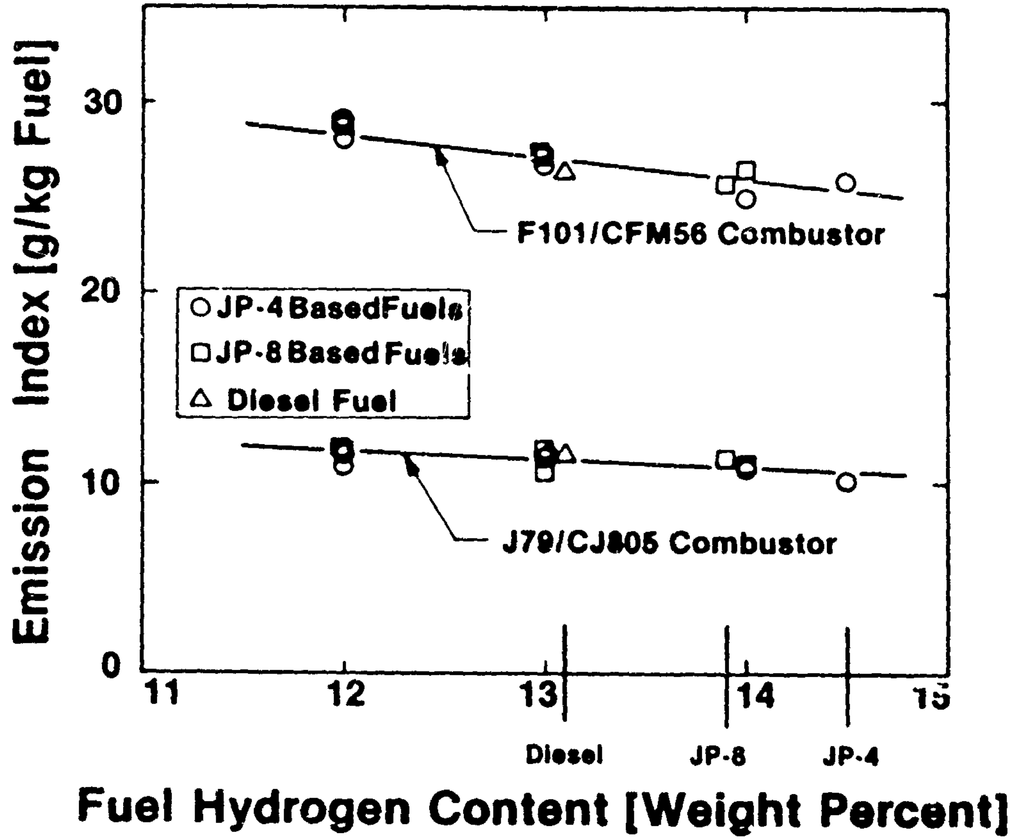
CF6-50 Combustor

● Component Test ● Takeoff Conditions



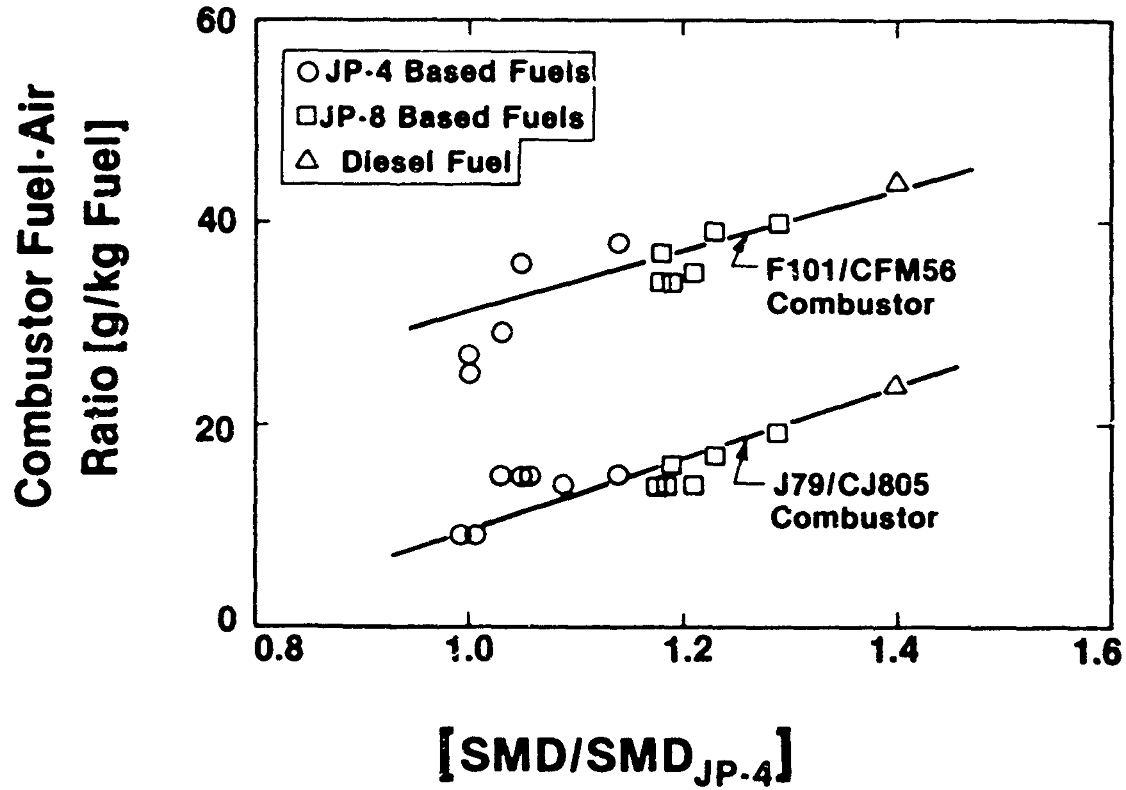
Effect On NO_x Levels

- Component Tests
- Takeoff Conditions



Effect On Lightoff Fuel-Air Ratios

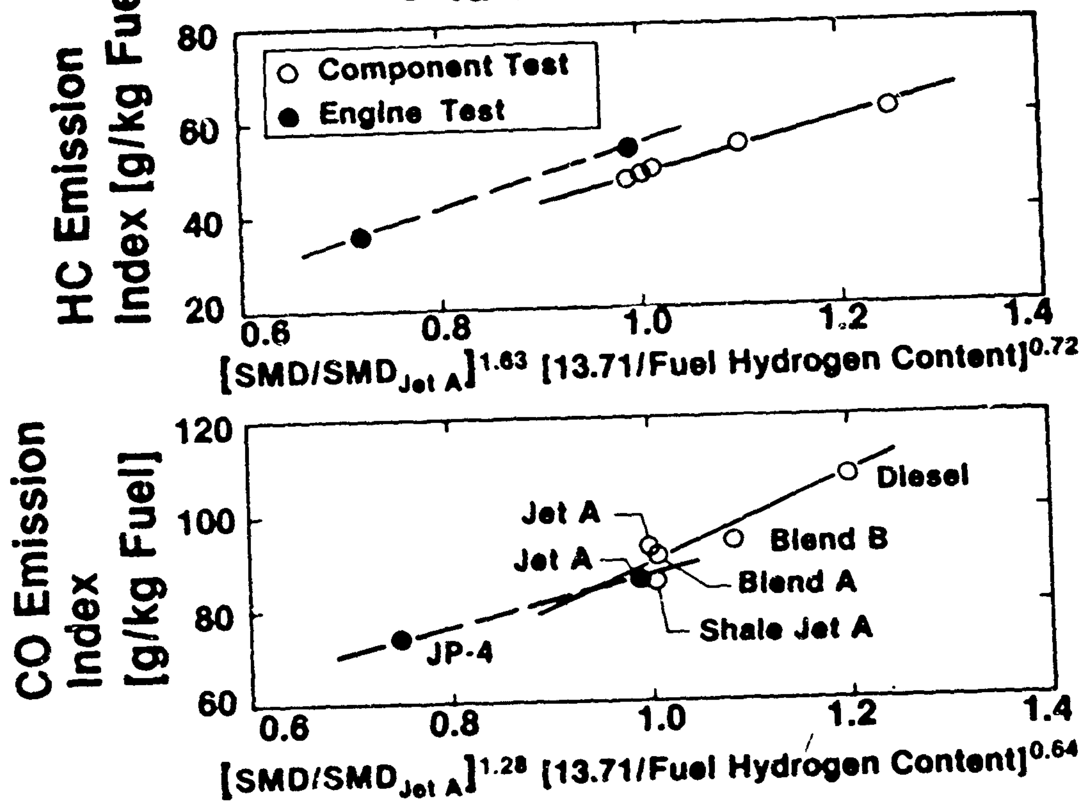
- Component Tests
- Ground Starting Conditions



Effect On HC/CO Levels

CF6-50 Combustor

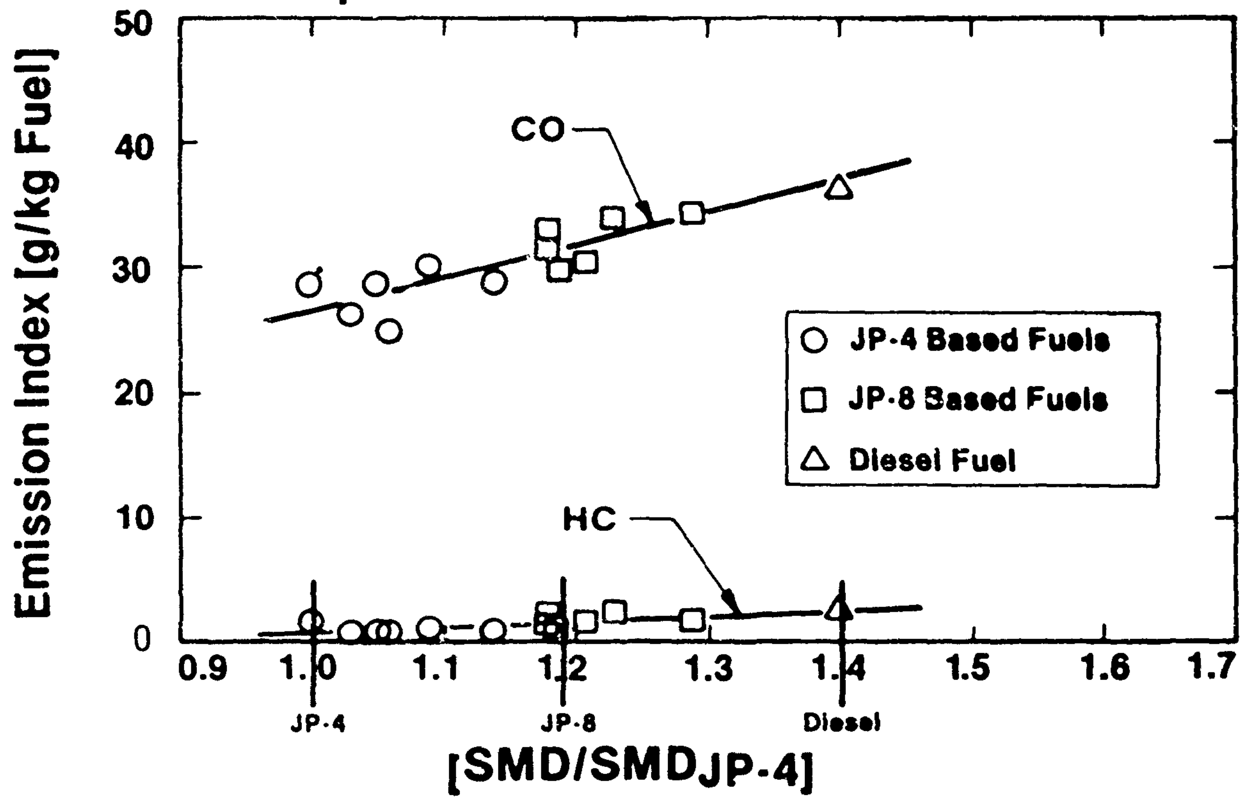
● Idle Conditions



Effect On HC/CO Levels

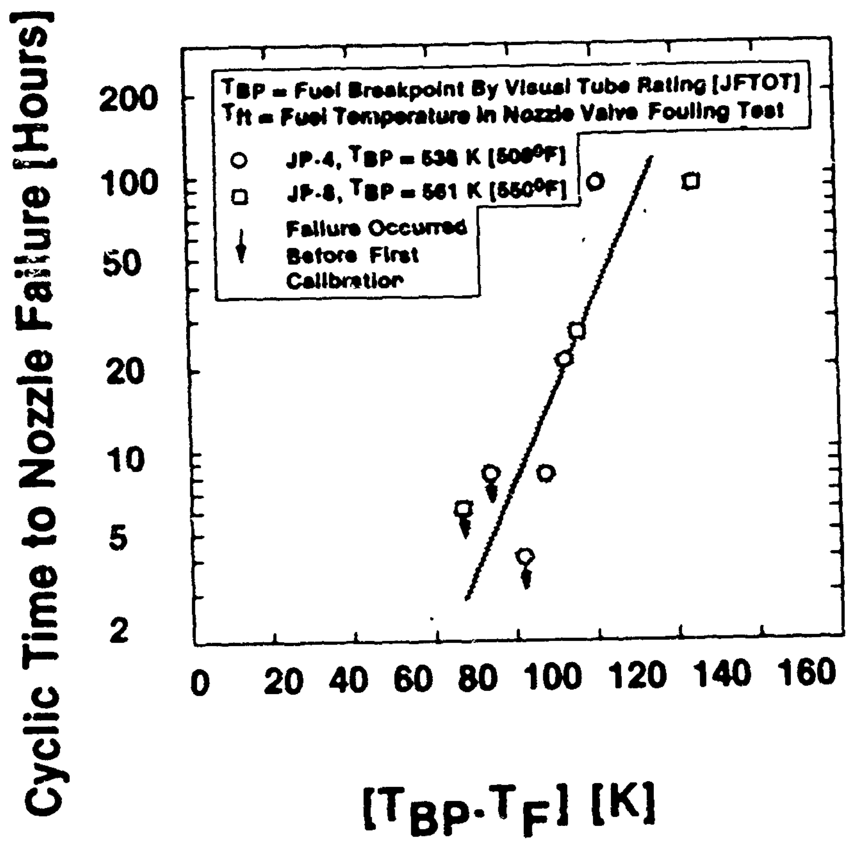
F101/CFM56 Combustor

- Component Test
- Idle Conditions



Effect On Fuel Injector Performance

F101/CFM56 Injector



Use Of Broadened Specification Jet Fuels

Key Concerns

- Increased Smoke Levels
- Increased Combustor Metal Temperatures
- Decreased Starting/Relight Capabilities
- Increased Fuel Injector Fouling Tendencies

Accomodation Of Broadened Specification Fuels

Current Technology Combustors

Design Provisions Which May Require Modification	Key Concerns/Impacts Associated With Fuel Property Changes			
	Smoke Emissions	Metal Temperatures	Starting/ Relight	Injector Fouling
• Fuel Delivery/Distribution				X
• Fuel Atomization-At Low Power			X	X
• Fuel-Air Mixing	X	X		
• Combustor Dome/Liner Cooling		X		
· Methodology				
· Construction				
· Thermal Barrier Coatings				
· Materials				

Fuel Effects

on

Airplane Fuel Systems

by

Frederick F. Tolle
Propulsion Research Manager

BOEING MILITARY AIRPLANE COMPANY

A Division of The Boeing Company o P.O. Box 3707 o Seattle Washington 98124

For Presentation at the
1980 Military– Industry Energy Symposium
San Antonio, TX
October 1980

FUEL EFFECTS ON AIRPLANE FUEL SYSTEMS

Frederick F. Tolle
Boeing Military Airplane Company

INTRODUCTION

Airplane fuel system designs must accommodate in an optimal way to a variety of fuel characteristics. The list of fuel characteristics that impact design is large; Table 1 lists some of the major design concerns.

TABLE 1
FUEL SYSTEM DESIGN CONCERNS

FUEL CHARACTERISTICS	SIGNIFICANCE
Flash Point	Safety Engine re-light at altitude
Heating Value per unit weight per unit volume	Range in weight limited systems volume limited systems
Viscosity	Boost pump power Line size and weight
Thermal Stability	Gum, deposits, nozzle coking
Specific Heat	Avionics and engine oil cooling
Aromatics	Sealants, combustor life, smoke
Freeze Point	Fuel feed after long duration cold soak

Because of a recent proposal to increase turbine fuel freeze point, the last listed item has been selected to illustrate how fuel specifications effect airplane design. The intent of the freeze point change would be to provide the petroleum industry with greater flexibility in meeting jet fuel requirements with the hope of favorably impacting cost and availability. The increase in freeze point would be brought about by broadening the refiner's cut of jet fuel to include higher boiling point fractions. This proposal has caused a flurry of activity among Government agencies, petroleum producers, and engine and airplane companies; activity at Boeing provides the basis of this paper.

FREEZE POINT

From the airplane standpoint, the freeze point specification derives from a concern for low temperature flowability of the fuel itself (water ice from water which may be dissolved in the fuel falls into a different problem category). Meteorological studies show that long duration high altitude flights expose airplanes to static air temperatures in ranges as low as -72C on a one time/year basis (fig. 1). However, the airplane exposure is eased for typical subsonic jet airplanes (M 0.84) by aerodynamic heating which raises the potential cold soak temperature for the fuel system to the vicinity of -47C. Existing specifications aimed at insuring jet fuel flowability at such low temperature stipulate a maximum allowable freeze point. Even so, infrequent but costly instances of fuel temperature difficulties do occur which interfere with flight operations. It can be anticipated that the frequency of these instances would increase with higher freeze point fuels.

A few background observations on the behavior of fuel at low temperature provide perspective on the nature of the problem. Fuels consist of a mixture of paraffinic, naphthenic, and aromatic hydrocarbons with a variety of crystallization temperatures as pure compounds (fig. 2); on dropping the temperature of a mixture of these compounds, the high freezing point materials which would solidify at a given temperature if pure tend to be soluble in the lower freezing fuel constituents. As a result, during cooldown the first appearance of solids in a mixture is deferred; however, as temperature is further decreased, a solid phase consisting of isolated crystals of long chain paraffins eventually begins to appear. As the temperature continues to drop, the crystals grow and merge into a spongelike matrix which eventually traps the remaining liquid phase. At this point the semi-solid may resist flow to the fuel tank outlet. Agitation (from gusts and aircraft vibration) or the use of flow improvers can interfere with matrix formation and maintain a flowable two phase slurry. The stages of conversion from liquid to solid as a function of airplane altitude are depicted in figure 3, and properties of interest are defined in figure 4. (It is of note that fuel is a very good thermal insulator, akin to rubber, and has a relatively high heat capacity, about half that of water.) As fuel temperature drops below the freeze point, the transition from a flowable to a non-flowable fuel often occurs over a range of a few degrees of temperature. A device known as the Shell-Thornton tester has been used to experimentally study holdup (amount of non-flowable fuel) as a function of temperature, with results for a typical commercial fuel as shown in figure 5.

FLOWABILITY PROBLEMS

Military JP-4 fuel has such a low freeze point that flowability problems have never developed in service. However, other fuels (commercial Jet A and Jet A-1, and military JP-5 and JP-8) and certainly fuels with relaxed restrictions on freeze point have the potential for creating operational difficulties. In recognition of this fact, many commercial airplanes already incorporate fuel tank thermocouples; in the case of the 747, when the sensed fuel temperature is within 3C of the specification freeze

point, the airplane flight manual requires that the flight profile be altered to increase skin temperature by changing altitude, Mach number or route. For the 747, the fuel consumption penalty for an 1850 KM (1000 NMI) deviation was assessed for a 9260 KM (5000 NMI) flight; the data shown on figure 6 indicate the added cost and reduced range for either descent to a lower altitude, or a Mach number increase. In order to avoid these penalties, airline operators along polar routes (during severe low temperature operations) may be forced to use Jet A-1, the higher cost lower freeze point alternative to Jet A.

Concern about safe operation limits with existing fuels, as well as the question of the acceptability of higher freeze point alternative fuels has shown the need for detailed studies of the flowability problem. These studies initially focused on understanding freezing phenomena as a function of temperature along a flight trajectory, using a combination of

- o in-flight measurements
- o ground simulation
- o analysis

More recently, additional effort has been expended on devising techniques to mitigate low temperature flowability problems by in-flight addition of heat to the fuel.

FUEL TEMPERATURE OBSERVATIONS

In-flight observations of 707 fuel tank temperatures showed significant vertical variations in fuel temperature (fig. 7), attributable to the very low thermal conductivity of fuel, and limited mixing in the tanks. However, the study of actual freezing phenomena could not be carried out in flight for reasons of safety and practicality. Accordingly, a fuel tank simulator representing a section of a 747 outboard wing tank (fig. 8) was constructed, containing typical wing tank structures and plumbing. The simulator (figs. 9 and 10) has been mounted on a slosh/vibration table to represent airplane motions. Slosh was modeled in one test as shown in figure 11. Upper and lower simulator skin temperature can be closely controlled in the range of -72C to 35C as a function of time. A central array of thermocouples gives continuous temperature data.

The simulator was recently used for CRC/USAF (ref. 1) sponsored experiments on five fuels, with the objective of measuring unavailable (holdup) fuel after severe thermal exposure. Test fuel characteristics are listed in figure 12. The mission which was simulated was launch of airplanes from an Arctic base to airborne alert status, calling for low speed flight in a holding pattern in Artic air masses. The experimental procedure called for pre-chilling the fuel to a temperature 10 to 20C above the freeze point, and then rapidly dropping the skin temperature to 10C below the freeze point. The temperatures in the tank were monitored to establish the time-wise variation of the shape of the thermal profile in the tank (fig. 13). The experiment was stopped when a thermocouple mounted 2.5 cm above the lower skin sensed a "target" temperature, at which time a holdup measurement was made by weighing the liquid fuel which could be drained from the simulator. The target temperatures used were +2.8, 0.0, -2.8 and -5.6 C with respect to the measured freeze point of the fuel.

Only limited results are reported here (a detailed report will be published by the CRC in the near future). For example, holdup data on one of the Jet A fuels indicates decreased holdup resulting from slosh/vibration agitation (fig. 14). It also appears from this test that slosh is more effective than vibration in reducing holdup. The thermal profile data is also useful in understanding the heat transfer mechanisms between the fuel and the tank walls. For full fuel tanks, the time variable thermal profiles (fig. 15) reveal three distinct regions:

- at the lower skin, a steep gradient in a zone controlled by conductive heat transfer
- at the upper skin, a very steep gradient in a zone where heat is transferred by free convection giving rise to downward movement of cold dense fuel
- at the center, a zone of little or no gradient resulting from convectively-driven mixing, with cold fuel descending and warm fuel rising; the cold fuel does not possess enough momentum to penetrate the lower zone controlled by conduction.

If fuel is withdrawn from the tank, the appearance of the thermal profile changes markedly. As the fuel loses contact with the upper surface, convection currents damp out, and the primary heat transfer is by conduction through the lower surface (fig. 16).

DESIGN ANALYSIS

Experimental observations have helped analysts to formulate a variety of computer technique. The first example is used for calculating fuel temperature profiles in full tanks; a comparison of calculation and experiment shows good agreement (fig. 17). The computer program is being extended to include the case of partially empty tanks. Ultimately, the completed package will be incorporated into Boeing's aircraft fuel tank thermal analyser (AFTTA) code to permit the designer to "fly" various en-route thermal exposure patterns, study fuel temperatures versus time, and determine holdup.

If analysis shows holdup to be unacceptable, Boeing studies funded by NASA (ref. 2, 3) of fuel tank heating or skin insulation provide the basis for a designer to do trade studies of fuel properties versus airplane fuel tank complexity and operating costs. Two conceptual designs for fuel heating system appear feasible based on analysis conducted with the existing AFTTA code (which uses bulk mean fuel temperature rather than thermal profiles). The first design (fig. 18) uses heat rejected by hot engine lubricating oil, while the second (fig. 19) uses a dedicated electrical generator driven directly by the engine to power an electric fuel heater. A trade study (fig. 20) was made on each heating system to determine what incremental cost reduction in fuel price would be required to offset the cost of acquisition, installation, maintenance and loss of payload attributable to the heaters. As noted in the figure, engine oil heat was found to be insufficient to permit use of -18 C freeze point fuel. Needed fuel cost reductions are in the fractional cents/gallon for a 5500 kilometer (3000 NMI) range airplane, but became as high as 17 cents/gallon at 9200 kilometer (5000 NMI) range.

Additional insights have been provided by a CRC/NASA funded study which used the AFFTA code. The study subject was a new class of long range high altitude business jets (ref. 1). The magnitude of the freezing problems that might be encountered and sensitivity to fuel loading temperature and thermal exposure profile were assessed. The study used actual fuel tank geometry, fuel withdrawal data and time variable thermal exposure to calculate bulk mean temperature. The results presented in figure 21 show that the fuel temperature at the end of five hours depends primarily on the lowest temperature of exposure, and little on loading temperature or on variations in the thermal exposure profile. An evaluation of the accuracy of the computations was made by comparing actual business jet inflight data and the results of computer analysis. A plot of the data (fig. 22) indicates good agreement.

SUMMARY

The magnitude of the effort associated with the study of higher freeze point fuel illustrates the sensitivity of the airplane and its fuel system design to fuel spceifications. The effort expended also goes far to explain the reluctance of system designers to accept fuel specification changes.

REFERENCES

1. CRC Contract No. CA-58-78, "Low Temperature Jet Fuel Study", 5 March 1979.

2. Pasion, A. J. and Thomas, I., "Preliminary Analysis of Aircraft Fuel Systems for Use with Broadened Specification Jet Fuels", NASA CR-135198, May 1977 (Contract NAS3-19783).

3. Pasion, A. J., "Design and Evaluation of Aircraft Heat Sources Systems for Use with High Freezing Point Fuels", NASA CR-159568, May 1979 (Contract NAS3-20815).

Figure 1. Inflight Altitude Ambient Temperature Profile

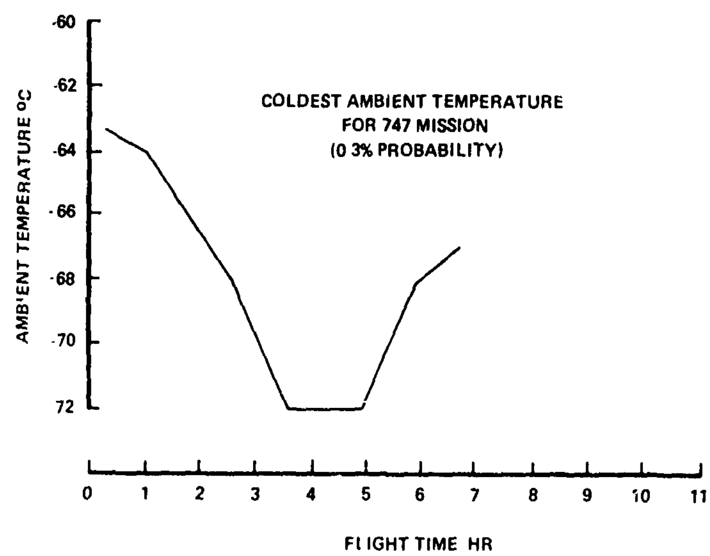


Figure 2. Variation in Crystallization Temperature for Various Single Compound Classes of Fuel Hydrocarbons

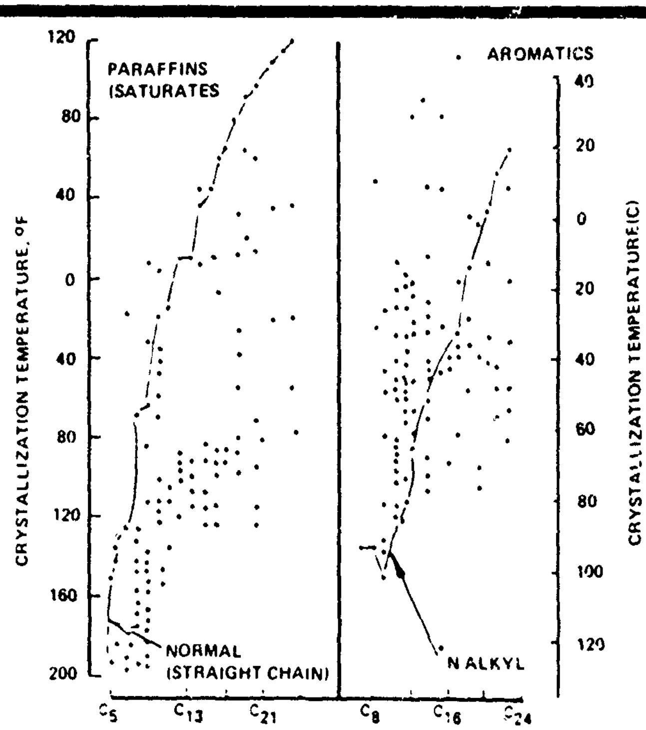


Figure 3. Low Temperature Behavior of Hydrocarbon Fuel

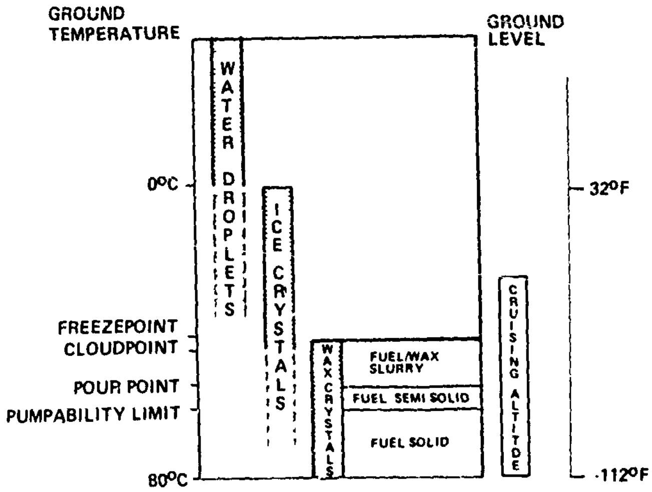


Figure 4. Low Temperature Properties

FREEZING POINT - THAT TEMPERATURE AT WHICH CRYSTALS OF HYDROCARBONS FORMED ON COOLING DISAPPEAR WHEN THE TEMPERATURE OF AN AGITATED FUEL IS ALLOWED TO SLOWLY RISE. ASTM D-2386

JET A	JET A-1	JP-4	JP-5	JP-8	BROAD SPEC FUEL
-40 C	-50 C*	-58 C	-48 C	-50 C	-34 C

* NOTE: ASTM HAS VOTED CHANGING TO -47 C

POUR POINT - RELATED TO THE LOWEST TEMPERATURE AT WHICH QUIESCENT FUEL WILL JUST POUR FROM A STANDARD GLASS CYLINDER OF 1-1/4" DIAMETER. THE POUR POINT IS 3°C ABOVE THAT FUEL TEMPERATURE WHERE NO FUEL MOVEMENT OCCURS WITH CYLINDER IN HORIZONTAL POSITION. ASTM D-97. (POUR POINT IS USUALLY FROM 3 TO 10 C LESS THAN FREEZE POINT)

HOLDUP - THAT FRACTIONAL AMOUNT OF FUEL WHICH WILL NOT FLOW BY GRAVITY FROM A CONTAINER BECAUSE OF PARTIAL FREEZING. IN THE SHELL-THORNTON TESTER, THE CONTAINER IS ESSENTIALLY ISOTHERMAL, AND 100% HOLDUP OCCURS BETWEEN FREEZE AND POUR POINT.

SPECIFIC HEAT (-40 C) 1.76 KJ/Kg - C

THERMAL CONDUCTIVITY (-40 C) 0.143 W/M - C

Figure 5. Shell - Thornton Holdup Data - Paraffinic Jet A

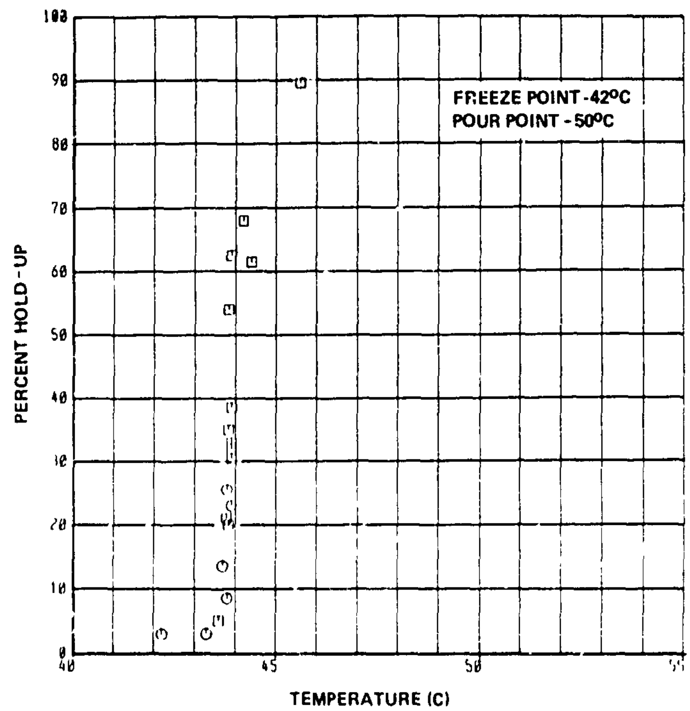


Figure 6. 747 Fuel Penalties for Flight in Cold Air Mass

BASELINE MISSION	
TRIP LENGTH	9,260 KM (5000 NM)
CRUISE MACH	.84
TRIP FUEL	117,930 KG (260,000 LB)
TRIP TIME	10.5 HRS
RESERVE FUEL	18,780 KG (41,400 LB)
ADDED FUEL FOR 1000 LOWER ALTITUDE	
-1220M (-4000 FT)	820 KG (1800 LB)
-2440M (-8000 FT)	2770 KG (6100 LB)
-3660M (-12000 FT)	5940 KG (13,000 LB)
ADDED FUEL FOR 1000 MILES AT INCREASED MACH NO.	
M = 0.87	1720 KG (3800 LB)
(TAT RISE +2.5°C)	

Figure 7. Stratification in an Airplane Fuel Tank (707 Outboard Reserve Tank)

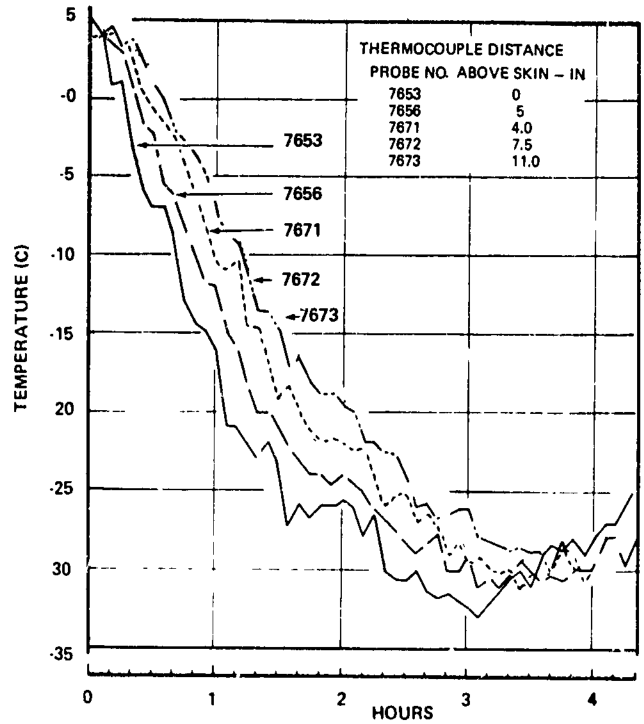


Figure 8. 747 Fuel Tank System

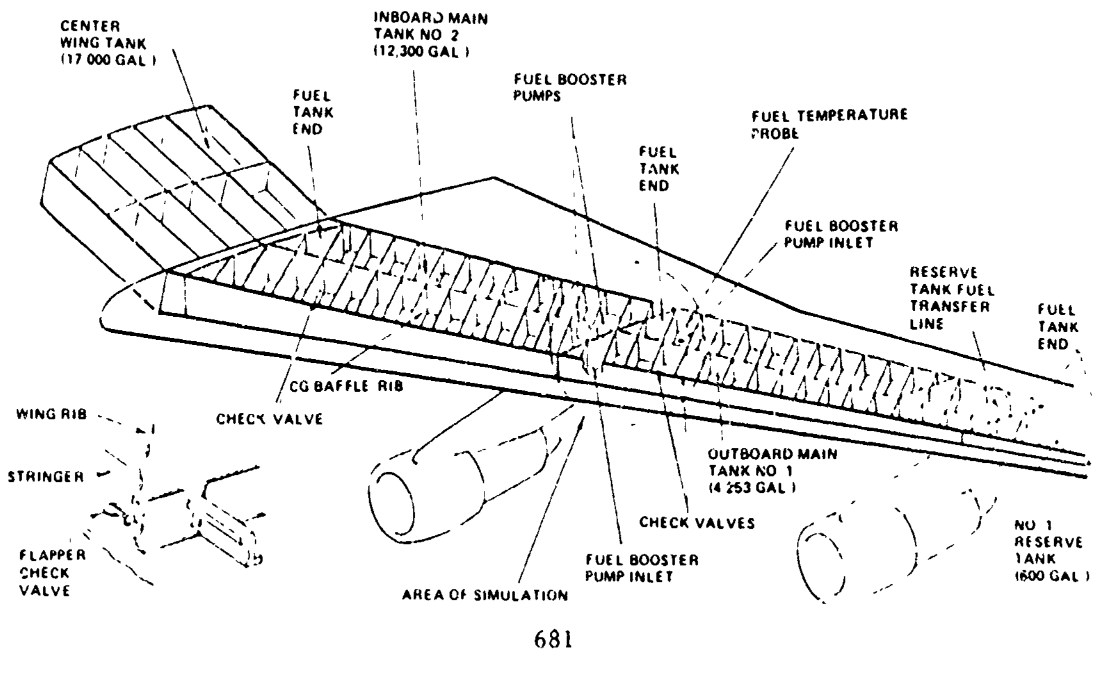


Figure 9. Fuel Tank, Thermal Simulator

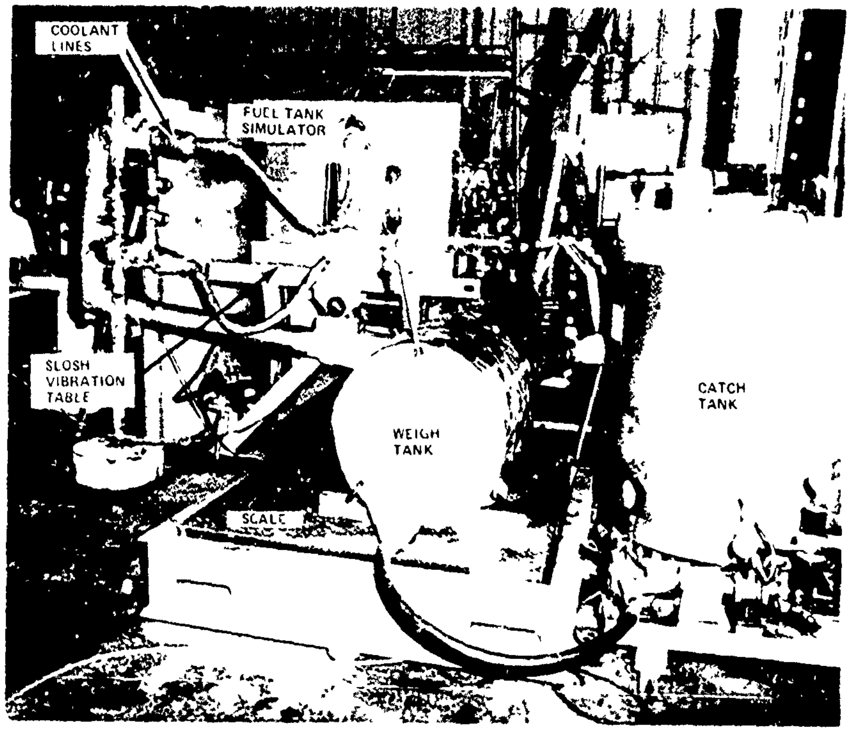


Figure 10. Interior of Fuel Tank Simulator

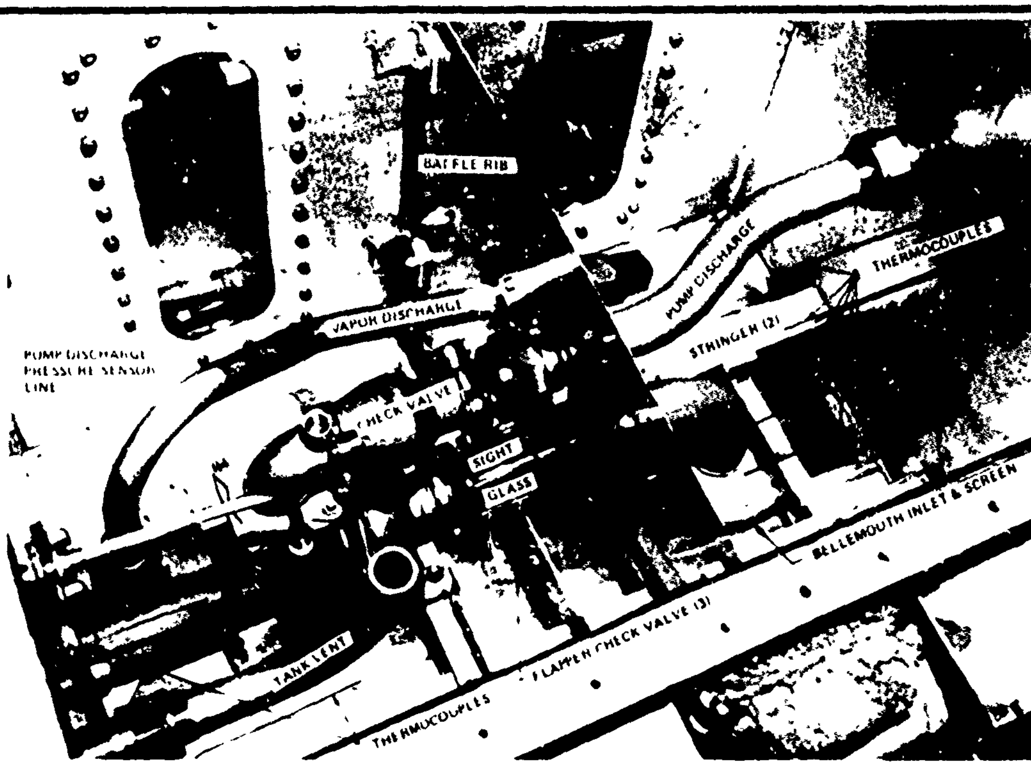


Figure 11. Simulated Gust and Maneuver (Slosh) Cycles

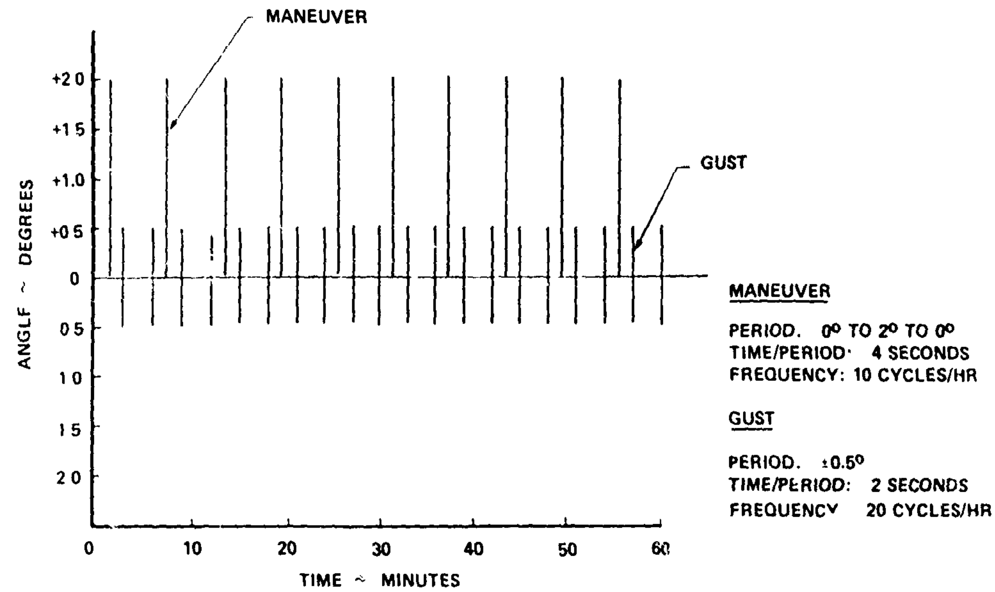


Figure 12. Test Fuel Characteristics

FUEL DESIGNATION	TYPE CRUDE	CRUDE SOURCE	FREEZE PT °C	(°F)	POUR PT °C	(°F)
JET A	PARAFFINIC	59% MINAS INDONEASIAN 41% MURBAN (ABU DHABI)	42	(43.6)	50	(58)
JET A	NAPHTHENIC	89% ALASKAN NO SLOPE 9% CALIF 2% MISC	51 1	(60)	52	(-61 6)
JP 8 (SHALE) MIL T 83133	SHALE		50	(-58)	53 9	(-65)
JP 5 + 9% DFM MIL T 83133			25	(-13)	51 1	(-60)
JP 8 (OUT OF SPEC)			-44	(47)	-48	(-55)

Figure 13. Time Variation of Fuel Tank Temperature

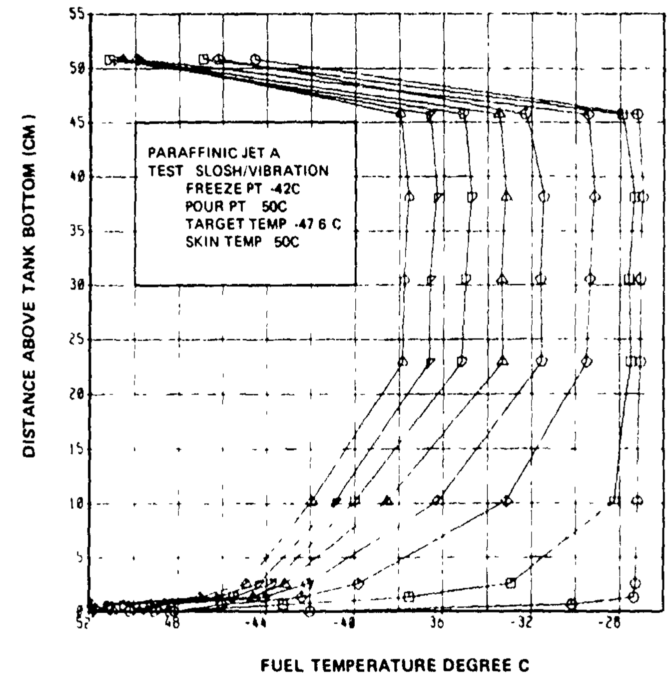


Figure 14. Effect of Tank Motion on Fuel Holdup

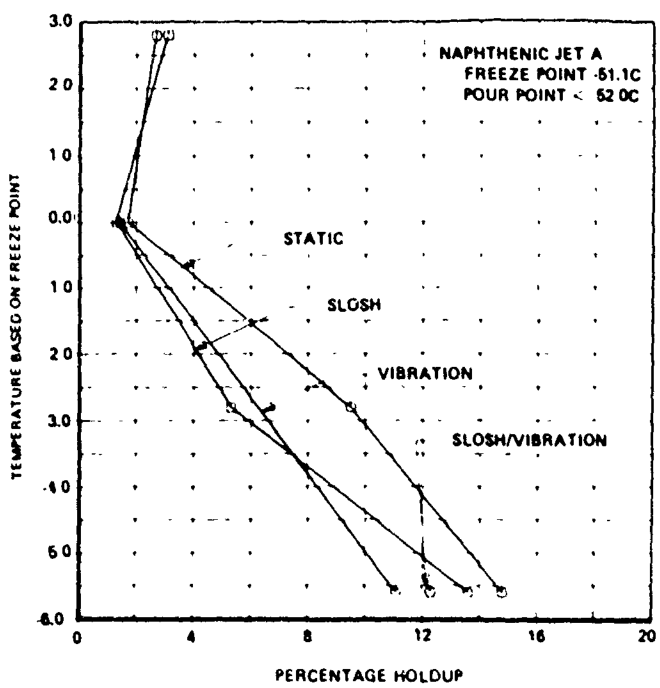


Figure 15. Temperature - Position Profiles for Jet A-1 Fuel and Wet Top Skin

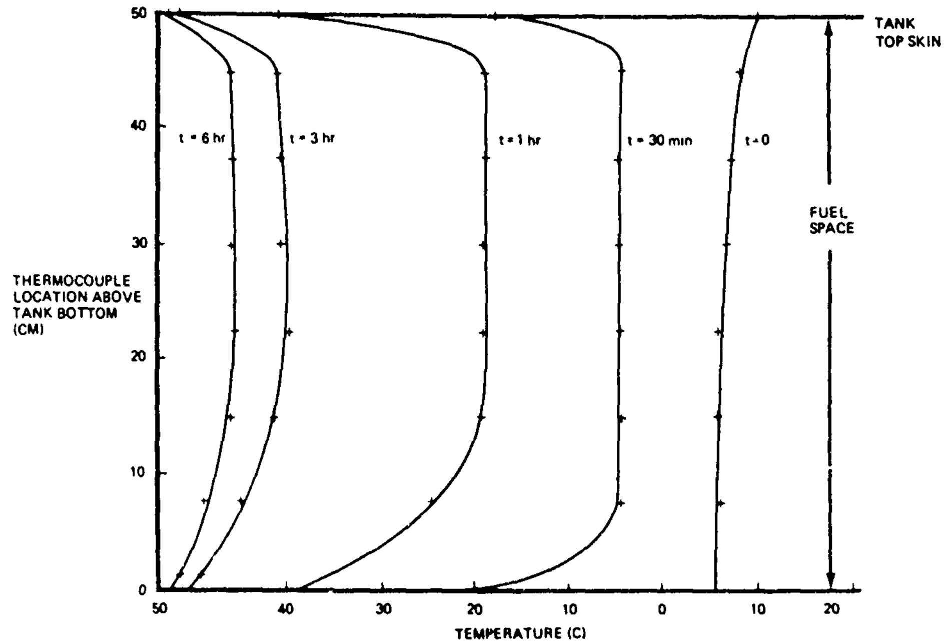


Figure 16. Temperature-Position Profiles for Jet A-1 and Dry Top Skin

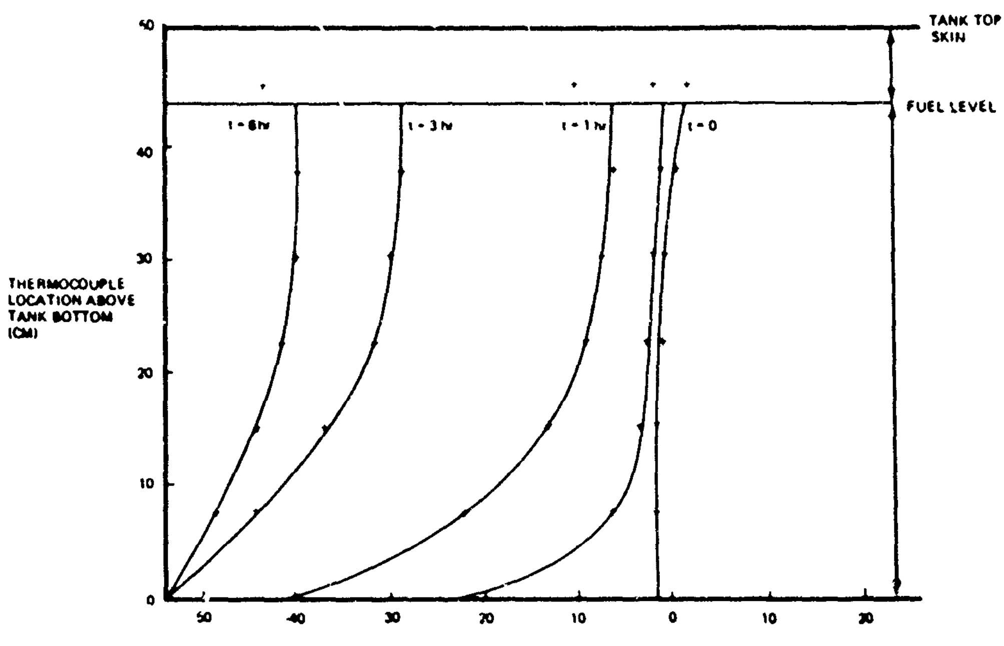


Figure 17. Comparison of Calculated and Experimental Fuel Tank Temperatures

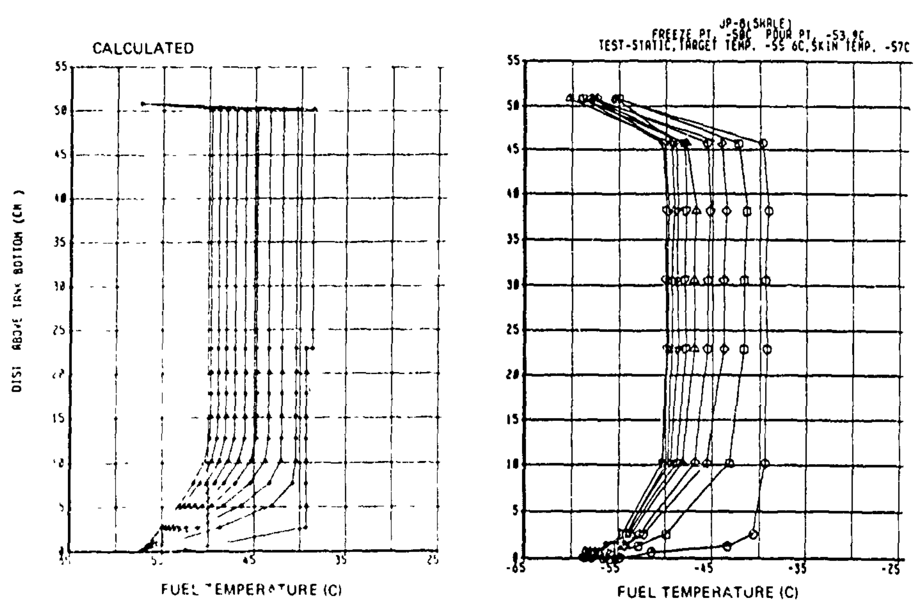


Figure 18. Fuel Heating with Engine Oil

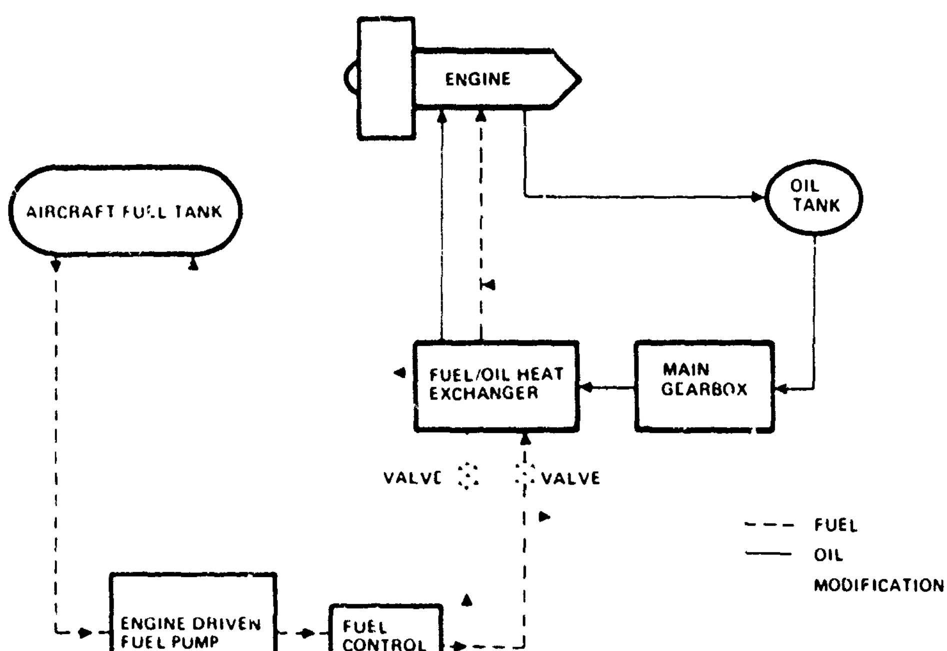


Figure 19. Fuel Heating with Electric Heaters

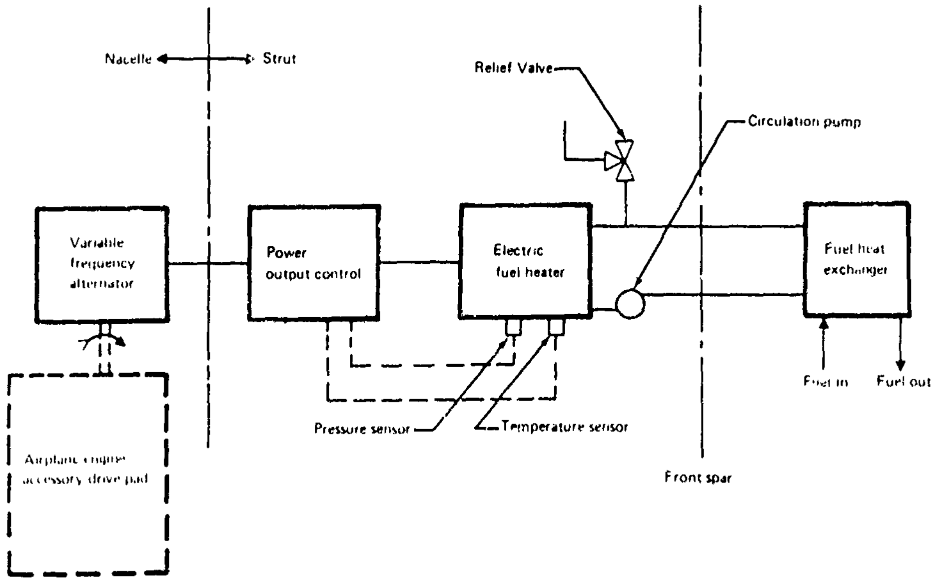


Figure 20. Return on Investment Study - 747 Airplane

FUEL PRICE INCREMENT REQUIRED TO BALANCE COST OF HEATING SYSTEM

FUEL PRICE BASIS: 45¢/GAL

3000 NMI FLIGHT

	-18°C F.P. FUEL	-29°C F.P. FUEL
ENGINE OIL HEAT EXCHANGER SYSTEM	XXXX	-0.29¢/GAL
ELECTRICAL HEATING SYSTEM	-0.90¢/GAL	-0.77¢/GAL

5000 NMI FLIGHT

	-18°C F.P. FUEL	-29°C F.P. FUEL
ENGINE OIL HEAT EXCHANGER SYSTEM	XXXX	-2.6¢/GAL
ELECTRICAL HEATING SYSTEM	-17.0¢/GAL	-12.3¢/GAL

XXXX CANNOT MAINTAIN ACCEPTABLE FUEL TEMPERATURE

Figure 21. Calculated Business Jet In-Flight Fuel Temperature

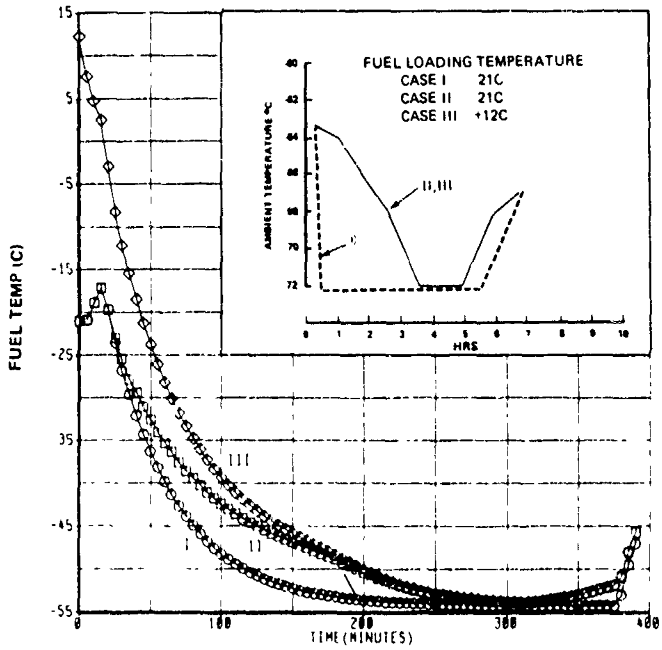
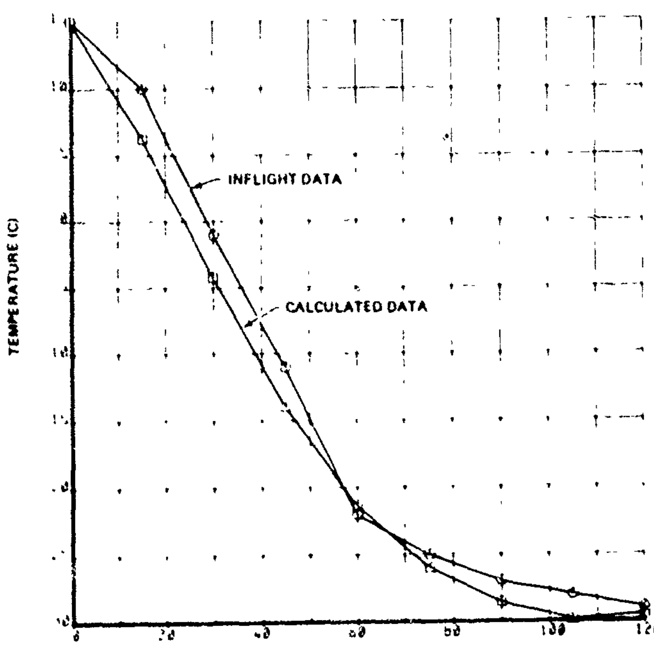


Figure 22. Business Jet, Wing Tank Fuel Temperature



FUEL/ENGINE/AIRFRAME TRADEOFFS

By

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INTRODUCTION

The Douglas Aircraft Company received a contract from the Air Force to study the effects of broadening the specifications for JP-4 and JP-8 fuel on the performance and cost of all USAF aircraft presently using JP-4 as well as those expected to be introduced into the force structure by 1983. Phase I of this study was to determine analytically the effects of these specification changes on minimizing fuel cost and maximizing the fuel availability/flexibility without degrading performance, safety, and survivability/vulnerability.

The maximum variations to the property specifications to be considered were as shown in Table 1. Union Oil Company was chosen to study the property variation effects on fuels, Pratt & Whitney Aircraft Group studied the effects on engines, and McDonnell Douglas studied the effects on the airframe.

TABLE 1
PROPOSED SPECIFICATION CHANGES

	JP-4	JP-8
FREEZE POINT, °F (°C)		
PRESENT SPECIFICATION, MAXIMUM	−72 (−58)	−58 (−50)
PROPOSED VARIATION	+14 (8)	+18 (10)
PROPOSED SPECIFICATION, MAXIMUM	−58 (−50)	−40 (−40)
FINAL BOILING POINT, °F (°C)		
PRESENT SPECIFICATION, MAXIMUM	518 (270)	572 (300)
PROPOSED VARIATION	+25 (14)	+25 (14)
PROPOSED SPECIFICATION, MAXIMUM	543 (284)	597 (314)
SMOKE POINT, mm		
PRESENT SPECIFICATION, MINIMUM		20[a]
PROPOSED VARIATION		−2
PROPOSED SPECIFICATION, MINIMUM		18

a MAXIMUM 3.0 VOLUME PERCENT NAPHTHALENES

HIGHLIGHTS OF FUEL SUPPLY STUDY

Union Oil obtained 24 foreign and 9 domestic crude assays which contained sufficient data to correlate freeze point and smoke point with initial boiling point and final boiling point. These and other data were examined to determine the effects on fuel availability, fuel costs, and hydrogen content (an important factor in engine life), when varying the fuel properties to the maximum amount shown in Table 1.

When comparing the change from theoretical yields of present specifications to proposed specifications, yields would increase as shown in Table 2. This large increase in JP-8 is due wholly to the extension of boiling limits in a narrow-cut product that are made possible by an extension of the freeze-point limits. Reasonable quantitative effects of fuel specification variations on military fuel prices could not be determined because of extreme market instability.

Seven selected crudes were analyzed for changes in hydrogen content which would result from the changes in specifications. Based on a similar weighting system as that used for volume effects, the change in hydrogen content is predicted to be 0.3 percent lower (0.17 wt percent H).

TABLE 2

EFFECT OF SPECIFICATION CHANGE ON YIELD

FUEL TYPE	PERCENTAGE INCREASE
JP-4	8.5-9.0
JP-8	41-62

HIGHLIGHTS OF ENGINE STUDY

The overall objective of the engine manufacturer's effort in Phase I was to assess the impact of broadened-specification fuels on the performance and durability of gas turbine engines used in USAF aircraft. The various engine-related parameters addressed in this phase of the program included ignition characteristics, combustion efficiency, emissions, thermal loads, burner exit temperature distribution, erosion, and coking of the fuel system. The sensitivity of these parameters was discussed with regard to the proposed relaxations of current JP-4 and JP-8 fuel specifications shown previously in Table 1.

A fuel characterization study was performed to determine the effects of the proposed changes in JP-4 and JP-8 fuel specifications on fuel hydrogen content. Through the use of interproperty correlations, a change from current JP-4 and JP-8 fuel values of final boiling point and smoke point to the proposed specification limits is predicted to decrease current fuel values of hydrogen content by 0.25 percent by weight.

Thermal analyses were performed on combustor liner and turbine airfoil temperatures in two USAF engines: the J57-59W and the F100-PW-100. Increases in turbine airfoil temperatures were found to be negligible for both engines (Figures 1 and 2).

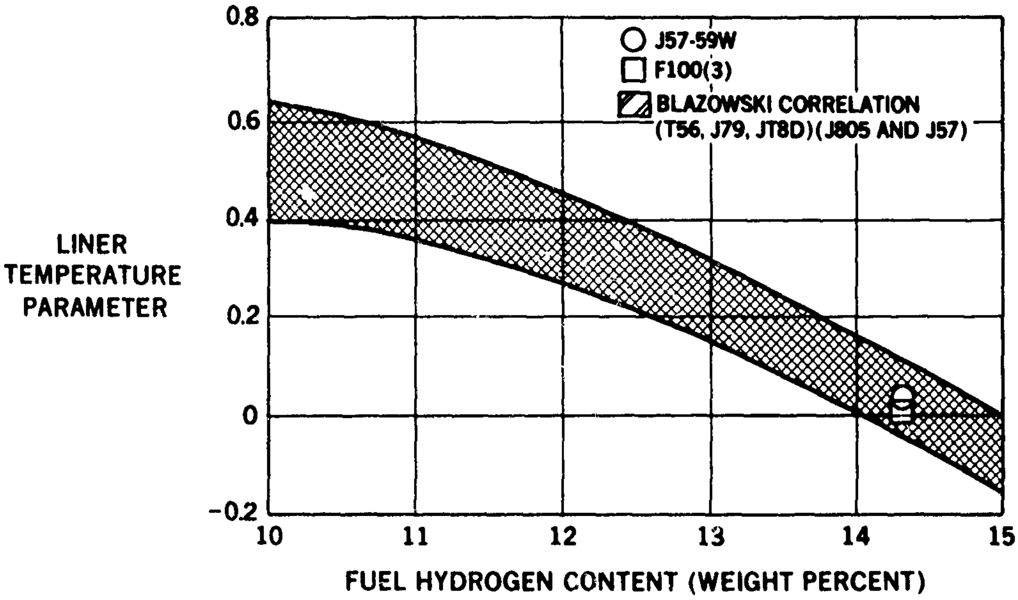

FIGURE 1. J57 LINER TEMPERATURE PARAMETER AT CRUISE CONDITION COMPARED WITH THE BLAZOWSKI CORRELATION

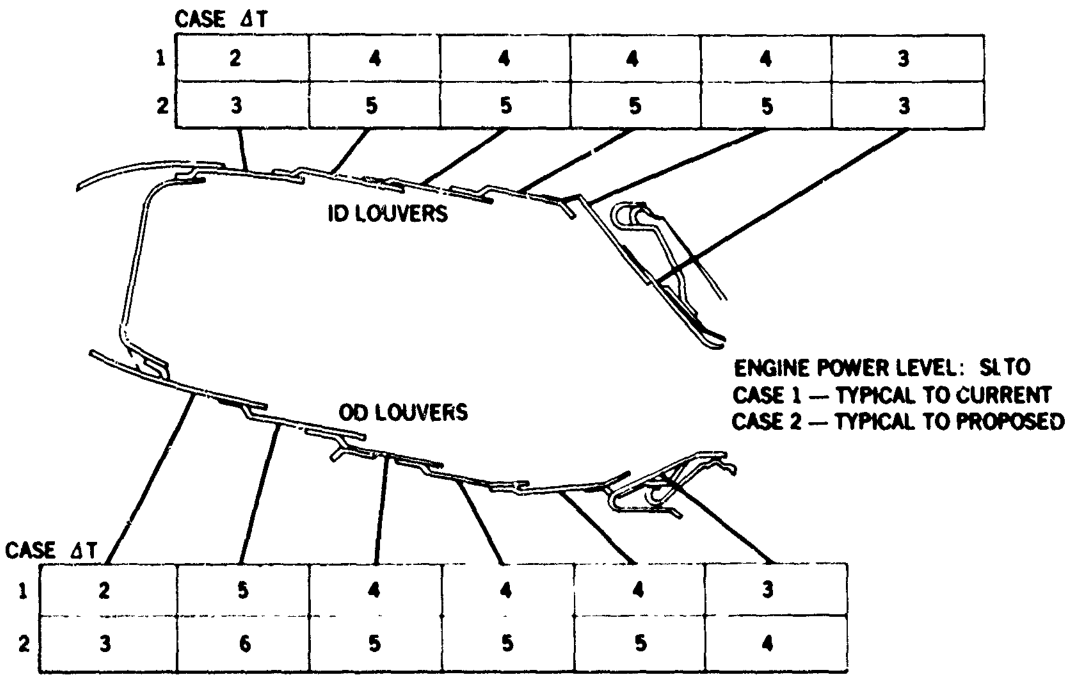

FIGURE 2. EFFECT OF FUEL SPECIFICATION RELAXATIONS ON INCREASE IN AVERAGE COMBUSTOR LINER TEMPERATURE

The Phase I effort concluded that there would be a small increase in maintenance costs due to a small decrease in combustor life. The study showed that the proposed relaxed specifications would have a negligible effect on visible smoke emissions. The broadened-property JP-4 and JP-8 fuels are expected to have no impact on engine performance, with the exception of

ignition capability, relative to current JP-4 and JP-8 fuels. The higher viscosity and lower volatility of the broadened-property fuels may have an adverse effect on ignition capabilities when fuel and/or air temperatures are relatively low (cold-day ground starts and altitude ignition). The extent of this effect depends on both operating conditions and the particular engine employed and cannot be predicted because of a lack of pertinent data. However, the incremental effect of the broadened-property fuels on ignition capabilities relative to current JP-4 and JP-8 fuels is expected to be less than the incremental effect associated with the use of JP-5 relative to JP-4 fuel.

HIGHLIGHTS OF AIRFRAME STUDY

The main objective of the airframe manufacturer's effort in Phase I was to determine the effect of broadened-specification fuels on aircraft fuel system performance. It was beyond the scope of this program to study all the airplanes in the Air Force inventory. "High fuel user" airplanes (Figure 3) were selected for this study. Together these aircraft consume 75 percent or more of the fuel used by the USAF.

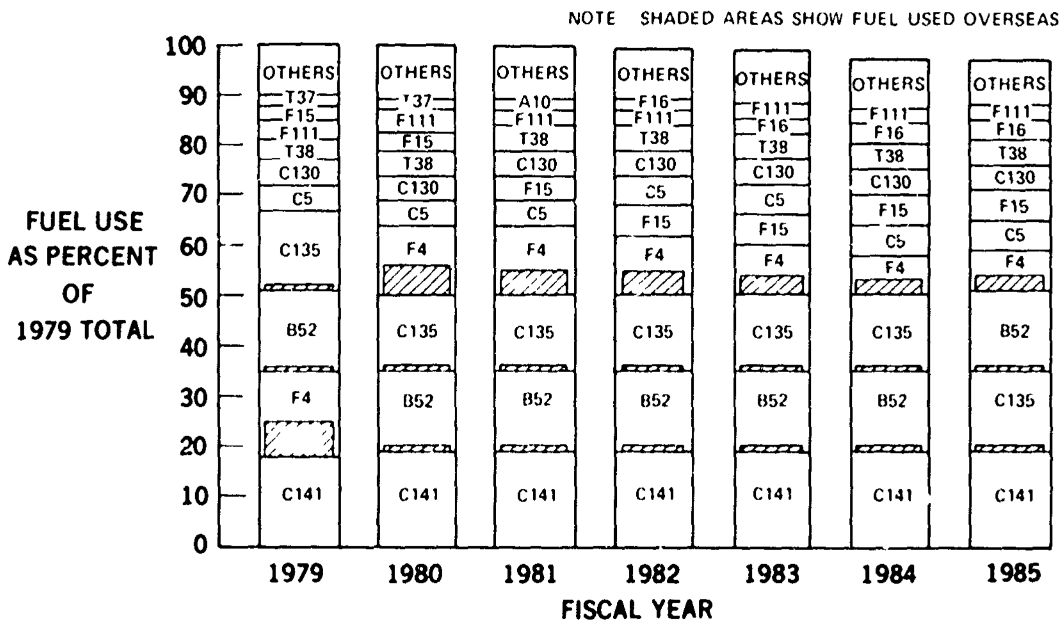

FIGURE 3 PROJECTED FUEL USE

The fuel systems and fuel management methods of each airplane were studied to evaluate the effect on the system performance of operating with tank fuel temperatures near the freeze point. The recovery temperature was used as a means of predicting minimum inflight fuel temperatures and the relationship with maximum allowable freeze points, using MIL-STD-210B as a basis for air temperatures. It is recognized that the use of MIL-STD-210B and the aircraft recovery temperatures is a fairly conservative approach; however, a less conservative approach could not be justified with the limited data that are available on this subject.

Using the selected approach, with some consideration of flight conditions (Figures 4 and 5), it was determined that all the airplanes in the study could obtain tank fuel temperatures below

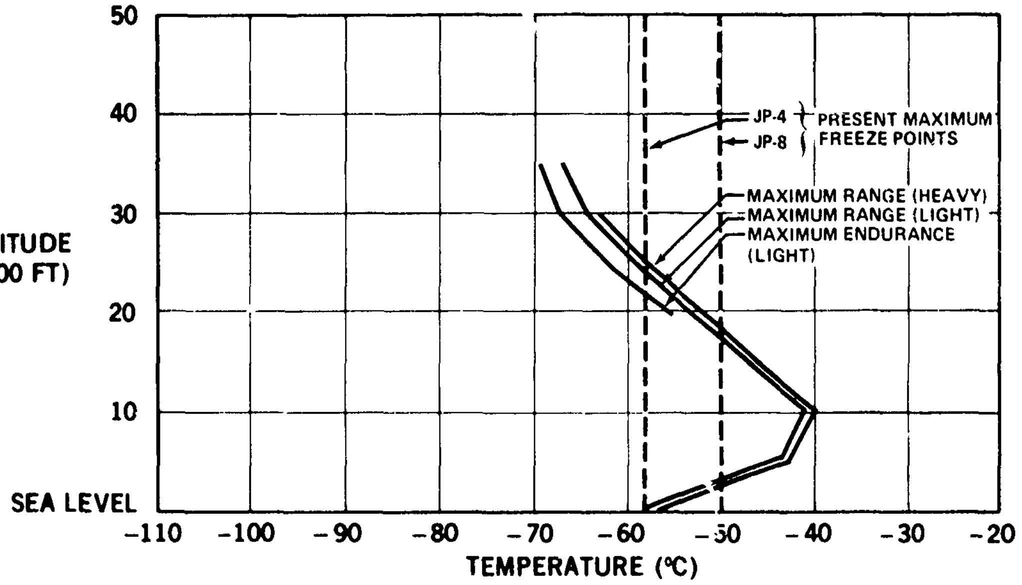

FIGURE 4. C-130 ADIABATIC WALL TEMPERATURE

NOTES:
1. OUTSIDE AIR TEMPERATURES FROM MIL-STD-210B, ONE DAY PER YEAR RISK MINIMUM TEMPERATURES
2. BASED ON ADIABATIC WALL TEMPERATURES

	KC-10A	C-9	B-52	C-130	C-135	C-141	C-5	F-4	F-15
JP-8									
MAXIMUM RANGE — HEAVY	0.5	−3.0	−5.0	−13.0	−4.0	−5.0	−3.5	4.5	1.5
MAXIMUM RANGE — LIGHT	−3.5	−6.5	−11.5	−16.5	−8.5	−9.5	−8.5	−0.5	−4.0
MAXIMUM ENDURANCE — LIGHT	−10.5	−14.5	−14.0	−19.5	−13.5	−18.5	−15.0	−7.5	−10.0
JP-4									
MAXIMUM RANGE — HEAVY	8.5	5.0	3.0	−5.0	4.0	3.0	4.5	12.5	9.5
MAXIMUM RANGE — LIGHT	4.5	1.5	−3.5	−8.5	−0.5	−1.5	−0.5	7.5	4.0
MAXIMUM ENDURANCE — LIGHT	−2.5	−6.5	−6.0	−11.5	−5.5	−10.5	−7.0	0.5	−2.0

FIGURE 5. ALLOWABLE FREEZE POINT INCREASE (°C)

the present maximum allowable freeze point of both JP-4 and JP-8. The most significant operating condition for this study is underlined in Figure 5. It was therefore concluded that the maximum allowable freeze point of JP-4 or JP-8 cannot be increased without degrading system performance and safety as critical conditions are approached.

CONCLUSIONS

Major conclusions from the fuel/engine/airframe tradeoff study were as follows:

1. An increased freeze point is questionable because of a data base problem.

2. There was no impact on engine performance, turbine durability, and coking.

3. There was a small maintenance cost increase as a result of a small decrease in the life of combustors.

4. Using JP-4 as standard fuel will avoid the use of high-demand middle-distillate fuels and will give producers flexibility.

5. Extensive use of JP-8 in the United States will increase middle-distillate demand and cause a slight increase in engine hot-section maintenance.

6. There is need for an accepted single-flight, cold-day atmospheric model.

7. Present aircraft operations and systems are freeze-point sensitive.

RECOMMENDATIONS

Recommendations for USAF action and further study are as follows:

1. An experimental study of the effect of fuel properties on engines should be made, including carbon formation, deposition, and erosion; fuel thermal stability and coking in actual systems; and afterburner performance and durability.

2. A combustor liner design with improved durability should be developed for both new combustor liner designs and retrofits.

3. The actual freeze point (not specification maximum) should be used for dispatch evaluations.

4. Aircraft systems and procedures for operations near the actual freezing point should be reviewed.

5. Tests should be conducted with special-blend fuel at broadened-property limits.

6. Future aircraft studies should include airplane and systems design-cost tradeoffs for higher freeze-point tolerance.

JP-8 CONVERSION PROGRAM

PRESENTED BY

WILLIAM J. RILEY
DIRECTOR OF FUELS
RAF MILDENHALL UK

PRESENTED TO THE
INDUSTRY-MILITARY ENERGY SYMPOSIUM
21-23 OCTOBER 1980
SAN ANTONIO, TEXAS

JP-8 CONVERSION PROGRAM

Good afternoon, I'm Jake Riley, Director of Fuels, HQ 3AF. I am located at RAF Mildenhall, in the United Kingdom. JP-4/JP-8 conversion in the UK was the first phase of the USAF program to convert all European forces to the use of JP-8 fuel. The objective of the fuel conversion program is two fold: First, to promote standardization and interoperability among NATO forces; and second, to enhance safety of operations. Presently, only France and the United Kingdom use JP-8 type fuel in their military aircraft, routinely.

The Air Force has over 9,300 aircraft in its inventory. The largest number of these are fighters, which are high technology, high performance aircraft. Our POL mission is worldwide and requires movement of large quantities of fuel often under adverse conditions. Last year we used 89 million barrels of oil for training and maintaining operational readiness and for ground support equipment. Aircraft operations account for 72.2 percent of our fuel bill and 99.7 percent of this is for jet fuel. So, any action we take on fuel standardization requires a hard look at supply availability and cost.

There is no doubt about it, we in the Air Force would like to have JP-8. In as early as 1965, the Air Force recognized a need for a more combat safe fuel. After considerable study, it was determined that the commercial Jet A-1 fuel would meet that criterion. The military designation chosen for Comm Jet A-1 was JP-8. JP-8 is a kerosene based fuel similar to the fuel used in commercial aircraft. But we add an anti-icing inhibitor for icing protection and biocidal control as well as a corrosion inhibitor to assure protection of our distribution system.

Comm Jet A-1 was an established fuel and readily available, except here in CONUS. The U.S. commercial type fuel is Comm Jet A. The difference being, the freeze point limits. Jet A-1 has a -47°C maximum freeze point, where as, Jet A has a -40°C maximum freeze point. Jet A-1 freeze point has just recently been raised from -50°C to -47°C. It is the opinion of the fuel suppliers, that a relaxation in this property, even by a few degrees, will assist in meeting continually rising demands for jet fuel. This action will impact on our JP-8 conversion program. In order to assure availability, and get a reasonable cost for our JP-8, the specification must parallel that of Comm Jet A-1.

When you think in terms of how much jet fuel we must have, availability becomes paramount. We have to accept trade-offs, like it or not.

First, lets take a look at where we have been. Prior to 1940, aviation gasoline was the only fuel used for aircraft propulsion. The introduction of the gas turbine engine in the post 1940 period required a different type fuel.

The first turbine fuel specification was prepared by the military departments and was issued in 1944 for a fuel designated as JP-1. This fuel had a minimum flash point of 110°F, for safety in flight as well as safety in ground operations, a minus 76°C maximum freeze point, to assure our needs at a high altitude and a boiling range between 300°F and 500°F. This product was and is recognized as an excellent jet fuel, since you got high flash and low freeze characteristics. This was a kerosene based fuel. This fuel is almost identical to what we know as JP-8 today, but in 1945, we had the same problem, availability.

As you can see, the problems we face today are not new. Thirty years ago, the flash point requirement was deleted and a wider boiling fraction was designated, in an effort to increase availability. Our new specification had a reid vapor pressure of 1 to 2 PSI. We called the new jet fuel JP-2. It was used only for experimental purposes. To solve the availability problem with JP-2, we increased the specification for the boiling range, which gave us a reid vapor pressure of 5 to 7 PSI. The new fuel was predominantly gasoline with a very small amount of kerosene in the mixture. While this fuel solved the availability problem, it resulted in excessive losses in the order of 20 percent, because of venting of liquid and vapor at high rates of climb and high altitude. This fuel was designated JP-3.

A major trade off came in 1951, when we settled on a wide cut mixture of naphtha and kerosene, it solved the excessive venting loss problem and met the requirements of insuring maximum availability, since there was no real market for naphtha. It also provided maximum aircraft operational performance, but it fell short of meeting our safety needs. Our past experience in the handling of aviation gasoline, prior to the jet age had taught us that a low flash point fuel could be used in aviation. If we strictly adhered to safety practices in handling of the fuels.

You would have thought we would be satisfied; we were. We enjoyed almost 30 years of buying fuel virtually at cost because there was no real market competition for this product. It was a convenience for the refiner to be assured that the naphtha portion of the barrel of crude would be sold. No doubt, this arrangement spoiled both the refiner and the Air Force. At the same time, we in the military agreed to accept a more volatile fuel, our commercial counterparts wanted a kerosene type fuel, which afforded that extra margin of safety. In 1958, ASTM came out with a specification for Comm Jet A. It met the requirements for domestic flights, but there were problems

anticipated for the low temperatures experienced during long range commercial flights. It was found, that in the worst case, the fuel could be exposed to static air temperatures in the range as low as -72°C (-97.6°F). Continuing study of the low temperature properties of fuel indicated that for typical subsonic jet aircraft, the aerodynamic heating will increase the potential cold soak temperature for the aircraft fuel systems to the vicinity of -47°C (-52.6°F). To assure the freeze point on long range commercial flights, a new specification was adopted by ASTM in 1959, Jet A-1 fuel, it is the same fuel as Jet A, but it had a -50°C freeze point.

By 1965, the war in Southeast Asia was going strong, it was like nothing we had experienced in the past. The Air Force and Army did not fly out of secure bases. Rapid turn around of aircraft was common, and of course, the weather was seldom under 95°F. Also by 1965, kerosene based fuel was at a premium because almost all of the airline companies in the world had recognized the extra safety afforded by a kerosene type fuel and switched from Jet B (commercial version of JP-4) to Jet A or Jet A-1. The reason for the change was safety, both in flight and during ground servicing operations. It was especially important in the event of a crash due to the lower rate of flame propagation. These extra few seconds meant a lot to the airlines.

In Southeast Asia, we learned a lot. There were definite advantages to having JP-8. It would provide an extra margin of safety in combat flying and it would greatly increase the safety during ground servicing of the aircraft. The new fuel, JP-8, was considered initially, as a replacement for JP-4 in Southeast Asia, but in 1968, the idea and applications were expanded to use it both for the Army and Air Force. DOD queried the department of interior on future availability if a decision was made to standardize on a kerosene based fuel. They advised that the product would be available, provided its use was phased in to allow refiners to make the necessary changes in the production cycle.

Again in 1973, the Interior Department was queried on the impact if we went to JP-8, we were again advised industry could not satisfy the military requirements for JP-8 in the short term, but the requirements could be satisfied in approximately three years, provided a phase in program was adopted.

I think we, especially those who have or are working with petroleum, recognize 1973 as "the year that was." During this time frame, more than 18 petrochemical plants were being built, and there were double that amount scheduled to be built before 1980. As you know, naphtha is the feed stock for the petrochemical industry. It was easy to see that the "honeymoon," we had enjoyed with oil companies, who had excess naphtha, would slowly come to an end. What we did not recognize was that the "seed" of the OPEC nations had started to sprout.

In November 1974, it was decided that due to fuel shortages and changes in the supply structure, procurement of sufficient quantities of JP-4 fuel might be difficult in the future. Of the several alternatives for dealing with the problem, it was our decision to maintain our specification, but consideration would be given on a case-by-case basis for specification waivers if necessary, and to switch from JP-4 to JP-8.

By the end of 1976, due to instability in the crude market, construction of petrochemical plants was falling behind. Most of the capital for the new plants was Japanese, and as of now, they are way behind. I don't think there is any doubt that in the 1980's, the demand for synthetics, in the auto industry alone, will spark the initiative to go on stream with a number of new petrochemical plants; thus, greatly increasing demands for the lighter boiling fractions, specifically naphtha, which will be the feed stocks from which our JP-4 is derived.

During this same time frame, it was agreed within the NATO alliance that every effort would be made to standardize on JP-8 for interoperability. There is much more Jet A-1 refined in Europe than JP-4. JP-8 would improve interoperability with the European commercial fuel and allow its use in a contingency. It would thus, greatly enhance our wartime capability. At present, there are 17 refineries connected into the Central European Pipeline System with more planned to come on line in the future. There would be a distinct advantage if we could use commercial type jet fuel.

In April 1978, the Air Force announced that it would begin its program to convert its European aircraft and bases from JP-4 to JP-8. The UK was a test site and was selected for the initial conversion inpart because JP-8 type fuel was already the primary fuel used. The first JP-8 was received into our UK terminal system on 3 May 1978, and was introduced into our first base (Upper Heyford) on 6 July 1978. The conversion in the UK was completed in June 1979.

We are now in a position, in the UK, to look at conversion with "20/20 Hindsight." From an operations view point, there have been many advantages as well as cost savings. The biggest advantage of using JP-8 is safety, under normal conditions encountered during the routine aircraft ground and flight operations, a low volatility fuel, such as JP-8 offers a significant fire safety advantage over higher volatility fuels such as JP-4.

I could easily talk for another hour explaining the higher probability of fire if you use JP-4 instead of JP-8 fuel. There is no doubt that the less volatile properties of JP-8 make it a much better fuel for use by our military. This is especially true in the European theater, where constant training and ordinary requirements such as hot refueling

(that's where we fuel the aircraft with the engines running) shelter refueling (that's where we fuel an aircraft in a hardened shelter) and simultaneous munitions loading (that's where we fuel and load ammo at the same time), are all common and greatly enhance our wartime capability and are much more hazardous with JP-4 than JP-8 fuel.

With the exception of leaking aircraft seals at the start of the JP-4/ JP-8 Conversion, there have been no major technical or operational problems in the UK.

The yellow flag has now been waved on the JP-8 conversion program. The original estimates that a cost difference would be minimal between JP-4 and JP-8 has not proven realistic. The price for JP-8 has increased far more rapidly than the JP-4 price. The differences have been about 10 cents a gallon higher for JP-8. We have found over this past eighteen months, JP-8 has been available, but we had to pay the going price. Defense Fuel Supply Center was tasked to perform a market analysis of Europe to evaluate conversion, unfortunately, the analysis was performed during the two years immediately before, during, and subsequent to the fall of the Shah of Iran. It is an understatement to say that the European market has been erratic during this period and the results of the market analysis certainly reflect the political events and market reprecussions. In short, the market analysis may not be indicative of future market conditions.

We have once again reached an impass on our fuel dilemma. There have to be some trade-offs and we are going to have to decide on a few in the next 10 years. Today we are in a position to make controlled trade-offs - tomorrow - who knows.

We should look at the effect on availability of jet fuel, Most Jet A-1 is produced from straight run distillates and, therefore, its availability does not depend on elaborate processing but instead is limited by the total amount of crude run, the quality of the crude and the demand for other products which utilize the same fraction. Looking at the typical boiling range of major refinery products, Jet A-1 is about 10 percent of the total. On this slide you can see the typical boiling range for the other products that compete with Jet A-1.

Naphtha, used as a petrochemical feed stock (and for our JP-4) and motor gasoline compete for the lighter end of the cut, and light gas oil (diesel fuel and domestic heating oil) for the heavier end of the cut. Heating/illuminating kerosene is not shown since most refiners manufacture it as a dual purpose product with Jet A-1. Surprisingly, there is a significant demand for this product, especially in the lesser developed countries. What I'm trying to get to is, in order to increase the yield of Jet A-1, from a given crude slate, the boiling range for Jet A-1 would have to be extended and/or material diverted from other products. The initial boiling point of Jet A-1 is limited by the flash point requirement, the lower the initial boiling point the lower the flash point. Studies show that relaxation of the flash point from 38°C to 32°C (worst case) (100-90) could permit the initial boiling point to be reduced by about 10°C. This would enable the potential yield of Jet A-1 to be increased by 7-10 percent, depending on the nature of the crude oil. Moreover, adding lighter hydrocarbons by reducing the initial boiling point in this manner affects other properties, such as freeze point, so that for a constant freezing point some additional higher boiling materials could be included, thus increasing availability. Let's take a look at a constant freeze point limit of minus 50°C, by reducing the flash point, you can considerably increase the yield. These yields are the best cases, representing straight run distillation cuts maximized assuming that the flash point requirements are the only limiting factor in the refining process. We know this is an ideal situation and other factors are involved especially the limiting effects of other properties and the demand for other distillate products have to be taken into consideration.

With many crudes, jet fuel yields are constrained not by the flash point and freeze point limits, but rather by the existing specification limits for other properties. The present limits on the combustion properties, namely, smoke point and aromatics content, impose the greatest constraint, and relaxations of these limits will be required before full advantage could be taken of a flash point relaxation. Although with some crudes, the present aromatics content and smoke point limits will become less critical if the flash point is lowered and more light end fraction is included in Jet A-1. This will limit the extent to which higher boiling material can be included to offset the front end added.

The point I'm trying to make is that there are trade-offs, and in my opinion, there are some rip-offs. If we are willing to broaden our specification properties, we should expect something in return to offset the modification/redesign cost to use it. For example, raising the freeze point, we would require some type of heating in the fuel tanks on some aircraft, or redesign of a combustor for the poorer quality fuel. Before we jump, let's make sure we can see that the light at the end of the tunnel is not a locomotive coming at us.

As far as safety, there is a trade-off on lowering the flash. Before we go too far, we have to remember, we have a lot of experience in using JP-4 with a flash point below -25°C, and you have to admit, we have an excellent safety record.

The product balance for our refineries here in CONUS is significantly different from the rest of the world. Let's take a look. Most forecasts indicate that here at home, we will see the demand for the middle distillates, especially Jet A-1 and diesel fuel,

continue to grow at a faster rate than motor gasoline, which is expected to slow down and after 1985 move into a reducing situation. Although the increased demand for middle distillates work against increased Jet A-1 availability, the decrease in gasoline demand could make lighter, more volatile fractions available which, if incorporated into jet fuel, would increase availability while maintaining a reduced flash point.

The forecast for Europe is a bit different. They anticipate the demand for motor gasoline will grow at a faster rate than middle distillates, which are also expected to grow. To meet these demands more fuel oil will be cracked to lighter fractions, the fuel oil will be replaced by other energy sources. This hopefully will lead to a product balance for Europe in the year 2000, rather similar to that here at home today, except that the European proportion of middle distillate yield will be somewhat higher.

No doubt, the price will most likely influence the direction we go in converting to JP-8. At least, I think we are assured it will slow down the pace at which we are going.

The decision to convert Europe to JP-8 fuel is still a sound one. It may be necessary to delay conversion until we decide which specification changes we can effect to improve availability and price while retaining added safety. This should please our counterparts in NATO who are now having second thoughts about price. You can't put a price tag on safety, however, with an additional flying range of 3 to 5 percent for JP-8, we can live with a 3 to 5 percent greater cost for JP-8 vs JP-4, and still get all that safety for free.

APPENDIX I

INDUSTRY-MILITARY ENERGY SYMPOSIUM

ATTENDEES

21 - 23 OCTOBER 1980

ADAMS, H. W.
STAUFFER CHEMICAL CO
WESTPORT CT 06880

ADAMSON, W.
HAMILTON STANDARD
WINDSOR LOCKS CT 06096

ALKIRE, M. G. COL
ATC/DE
RANDOLPH AFB TX 78148

ALLARD, JOHN M.
ASHLAND PET CO
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ASHLAND KY 41101

ALLEN, WILLIAM R.
ASD/ENFEF
WRIGHT PATTERSON AFB OH 45433

ALLIGOOD, BRUCE T. JR CAPTAIN
CO NAVAL AIR PROPULSION CTR
TRENTON NJ 08628

ALTER, WM.
GARSITE PRODUCTS, INC
10 GRAND BLVD
DEER PARK NY 11729

ANDERSON, MARLOWE R. LT COL
NATIONAL GUARD BUREAU
ANG SPT CTR/XOS
ANDREWS AFB MD

ANDERSON, RICHARD R. LT
23RD SUPPLY SQUADRON,
ENGLAND AFB LA 71301

ARMINGTON, ALLAN
DET 20, SA-ALC/SFQLB
P. O. BOX 408
SEARSPORT ME 04974

BAHR, DONALD W.
GENERAL ELECTRIC CO
STOP H-52 INTERSTATE 75
CINCINNATI OH 45215

BANIAK, EDWARD A.
TEXACO, INC
P. O. BOX 509
BEACON NY 12508

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ROSEMONT IL 60018

BARAKAT, MALEK
KUWAIT NATIONAL PETROLEUM
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NEW YORK NY 11020

BARNES, EDWARD J.
POWERINE OIL COMPANY
12354 E. LAKELAND ROAD
SANTA FE SPRINGS CA 90670

BARR, GENE H. MAJOR
DFR-NE
BLDG 1907
MCGUIRE AFB NJ 08641

BARR, ROBERT
GULF CANADA, LTD
P O BOX 4444
CALGARY ALBERTA CANADA T2P2H7

BARTELSON, LEO
TURBINE SUPPORT DIVISION
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BARTICK, HERBERT A.
TETRA TECH, INC
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MONTVALE NJ 07645

BECK, ROBERT W. SMSGT
12 SUPS/LGSF
RANDOLPH AFB 78148

BECKA, JOHN C. JR. MAJOR
SA/ALC/SFQH
KELLY AFB TX 78241

BEISSER· ED
PHILLIPS PETROLEUM COMPANY
758 ADAMS BUILDING
BARTLESVILLE OK 74004

BELLANGER, ANTHONY J.
DCASMA SAN ANTONIO
P. O. BOX 1040, DCRT-GSQ
SAN ANTONIO TX 78294

BELT, RUPERT D.
ASHLAND OIL, INC
P. O. BOX 1503
HOUSTON TX 77001

BENNETT, GEWN B. LT
1SOW/CVE
HURLBURT FIELD FL 32544

BERNATTI, GEORGE M.
DLA-QES
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CITIES SERVICE COMPANY
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BRIEN, TOM
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BURRIS, DARREL G. COL
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BURRIS, JUDY
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BUSCHFORT, H. G.
ALCOR, INC
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BUTTS, ROBERT L.
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CAMPBELL, TOMMIE L.
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760 ADAMS BUILDING
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